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THE A.W.A. REVIEW

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Foreword

Volume 19 of the *AWA Review* under a new editor presents some visual changes this year. These include the cover design, the layout of articles, and an abstract at the beginning of each article to introduce the reader to its content. The Review again brings a diversity of articles on the theme of wireless communications history.

- **Charles Kirsten** writes on early volt ohm milliammeters and describes why the Triplett 630 series deserves special attention in his judgment. His thorough treatment of the subject concludes that the 630's design embodied an integration of switching, insulation, housing and ergonomic features that resulted in a superior series of instruments.
- **Lloyd Jury and Brian Belanger** present a profile of Dr. David McCaa, a radio pioneer from the Pennsylvania area. McCaa's work is not widely known today, but the authors have turned up evidence of genuine achievements, including 36 patents related to radio and particularly to static reduction.
- **Neil Friedman** offers an annotated bibliography of amateur radio books published by *CQ Magazine* in the years from 1947 to 1984. Friedman writes interesting and candid profiles of each book and their authors.
- **Christopher Sterling** offers an appreciation of George Shiers (1908-83). Shiers was an individual from humble beginnings in England who rose through his lifetime to become a notable researcher of the history of electronics, specializing in the technical history of television.
- **Kent King and Norman Braithwaite** provide an update of their history of Scott radios which appeared first in Volume 11 of the *AWA Review*. This year's offering is an analysis of an extensive survey of serial numbers on extant sets, information that was not available from surviving factory records.
- **Gary Cain** presents a scholarly description of radio intelligence, the analysis of an enemy's radio signals to determine his capabilities, intentions, disposition and order of battle. The technique of radio intelligence was born in the First World War, and Cain traces its development from the early stages until modern times.
- **Donna Halper and Christopher Sterling** provide an analysis of how an event in the early history of radio is transformed into a legend. The event they chose to illustrate their analysis is the Christmas Eve 1906 broadcast of voice and music by Reginald Fessenden. In an exhaustive search they failed to find much documentary evidence that the

broadcast occurred on that day. They skirt heresy by suggesting that while Fessenden clearly was broadcasting around that time, several reasons may have influenced the result that the Christmas Eve date has been handed down to us.

- **David and Julia Bart** have traced the history if Morse code training in the United States. They are preparing to publish a book on this subject, and have favored us with a preview drawn from several chapters on Morse code training devices. It covers such devices as training keys, disk and drum devices, paper tape machines, audio visual trainers, oscillators, and phonograph and tape recordings. Use of these devices enabled thousands of telegraphers and wireless operators to work towards achieving greater proficiency levels and standards of performance.

Our thanks are due to these authors for providing the results of their fine work to the *AWA Review*. We hope you enjoy reading each of these contributions.

In striving to continue and improve the quality (and the perceived quality) of the Review, a practice of peer review of articles was introduced this year. For the majority of articles, reviewers were selected who had expertise in the topic area, and they were invited to comment on the submitted work. The reviewer's comments were relayed back to the authors. Articles reviewed in this way are noted as such at the end of the text. We hope the readership will appreciate the results of this change, so that it can be continued as a regular feature of the *AWA Review*. Peer reviewers for this volume were:

John Belrose
William Fizette
Robert Lozier
Tom Perera

We owe them a sincere debt of gratitude for their capable work.

AWA members and others with an interest in wireless communications history are encouraged to submit manuscripts to the *AWA Review*. A section titled Instructions for Authors follows. We try to make the publication effort more collaborative than challenging. The single most important message in this regard is to contact us early if you are considering writing an article.

It has been a pleasure (and a lot of work) to bring you this volume of the *AWA Review*. I hope you will find it as enjoyable to read as it was to prepare. Please do not hesitate to send me your comments on it.

Robert P. (Bob) Murray, Ph.D.
Editor

Tips for Authors

The *AWA Review* welcomes any submitted article on aspects of wireless communications history. In general, shorter articles can be directed to the *AWA Journal* and longer manuscripts to the *AWA Review*. If you are in any doubt about where your article should best appear, please contact either or both editors.

For first time authors, articles can be prepared with the help of a more experienced co-author, or the editor can help with the text in the editing process. Members with an interesting story to tell should not be discouraged by a lack of writing experience. The *AWA Review* will accept manuscripts in any clearly prepared writing style. A short style manual produced by the American Radio Relay League is available on request from the editor. *The Elements of Style* by William Strunk Jr. and E.B. White is available in most public libraries.

Reference material should be cited within the text of the article in any of the accepted reference styles. Reference lists should include all of the sources mentioned in the text. Writers should look at the articles in this volume or in previous volumes for examples.

Unlike writing for a regional club newsletter, articles submitted to the AWA will be laid out on pages in a style made consistent within the entire publication. Therefore, please do not arrange your illustrations on each page but rather send the text in a file separately from the files for each illustration. This requirement applies equally to the Journal and the Review. (see, for example, "From the Editor" in the *AWA Journal*, April 2006, pages 4 & 5.) Text files can be prepared on any word processing software, but preferably on Microsoft Word or on WordPerfect. Illustrations are best sent as .JPG or .TIF files with a resolution of around 300 dpi. Files can be submitted as e-mail attachments directed to the editor.

Articles submitted to the *AWA Review* should be developed in concept not later than early January of the publication year. A first draft should be submitted around March. The editor's deadline for submission of the completed volume to the printer is July 1, so that a final draft is expected around May 1. Articles not submitted on this schedule will be rescheduled for the next year's volume. For more information contact:

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AWA Review

The Extraordinary Triplett 630 VOM Series

Charles C. Kirsten©2006

ABSTRACT

Beginning in the early 1900s, analog moving coil meters saw great development during and after World War Two, reaching their peak in the late twentieth century. Triplett Instruments was one of the meter manufacturers who not only profited from the demand for good meters, but introduced quality construction combined with design innovations above the norm. Beyond producing a quality Volt Ohm Milliammeter (Model 630) that has enjoyed uninterrupted sales for over sixty-five years, Triplett offered several instruments with a price/performance ratio which has not been exceeded, or even equalled by recent analog meters.

EPIPHANY

I was a sick nine year old, and confined to bed, when a kindly neighbor gave me a crystal set with sensitive earphones. Suddenly my ears were filled with the incredible crystal-set clarity of the Wurlitzer Pipe Organ played by Jesse Crawford from the Radio City Music Hall in New York City. I was transfixed! Right in my rural "fiddlin', and foot stompin'" North Carolina environment, I was suddenly shown that all around me, silent and unseen, were programs and music of incredible beauty. All I needed was the equipment to capture them.

They say that if you give a child a hammer, all the world becomes a nail. Well, I had been given a pair of "phones", and all the world became a source of electrical signals. Ground one side of the phones, and attach a wire to the other side, and the whole space inside and outside of the house was filled with a low frequency hum. Insert a crystal detector, and every radio station and automobile ignition in the area was added to the clamor. Add a coil and condenser, and some of the voices could be separated out. It was like Aladdin's Magic Lamp. I caught the bug, and never recovered.

I listened on those phones across anything that might have electricity; batteries, capacitors, toy train transformers, phone lines. The wonder is that I didn't electrocute myself before I was ten, but I always returned to the beautiful music from the crystal radio. Eventually, I hankered for a way to see the amount of voltage in a battery, so I would know a weak one from a strong one.

I needed a meter. What does a boy know of economic depression? The quest of a penniless kid bartering among the poor black and white children of impoverished workers in a flour mill section of depression era South, for an electrical meter, is a pitiful story of jack-knives, marbles, and junk yards. I did get a few meters, automobile ammeters and watch-case type battery testers, but never one that worked on less than a heavy current drain. I guess I developed a case of meter envy.

THE WESTON 697, A GEM

Shift the scene to New York at age 16. I spent my summer time working for a retail radio store on Long Island. I knew more about electronics, and even owned a couple of moving vane 100 Ohms per Volt Readrite meters of my own. In my work as a radio repairer, one of the service instruments in the shop was a Weston 697 VOM (Fig. 1) which was the embodiment of the calibrated sensory yardstick I had always wanted[1]. It let me see, and quantify the invisible currents that made the radios work. That meter became my favorite instrument, and from 1938 on, the Weston 697 was my ideal of quality and integrated design of a serviceman's insulated, compact, Volt Ohm Milliammeter (VOM).

Fig. 1. Weston model 697 VOM

The meter was rugged. On several occasions my employer, who was inclined to talk with his hands while holding the test prods, had pulled the meter off the test bench onto the concrete floor. I too, on several occasions, had accidentally applied very high voltage to low range scales causing the meter needle to slam violently to the end of its scale. The meter showed no ill effects from this raw abuse, and still maintained it's extraordinary accuracy.

My admiration for the Weston 697 finally led to an analysis of the meter, and why it is such an outstanding performer. This review article describes the exemplary qualities of integrated design and engineered reliability found in the little Weston 697 VOM, and appears in the *AWA Journal*, January and May, 2006[2].

THE SIMPSON 260

Navy service in World War II found me trained as an Electronic Technician's Mate 2/C, installing and repairing radio, RADAR, and SONAR equipment on warships in Guam's Apra Harbor. Naval custom

dictated that a responding technician use the service instruments found on board the ship under repair, so often I would use a Simpson 260 VOM (Fig. 2), a reliable standard of the Navy since 1939, or some similar instrument[3]. As I remember I appreciated the performance of these meters, for all of them including the Simpson 260 had to meet strict military specifications. They all were made of high quality parts. An unintended result was that, "G.I." multipurpose meters often looked more like quality as-

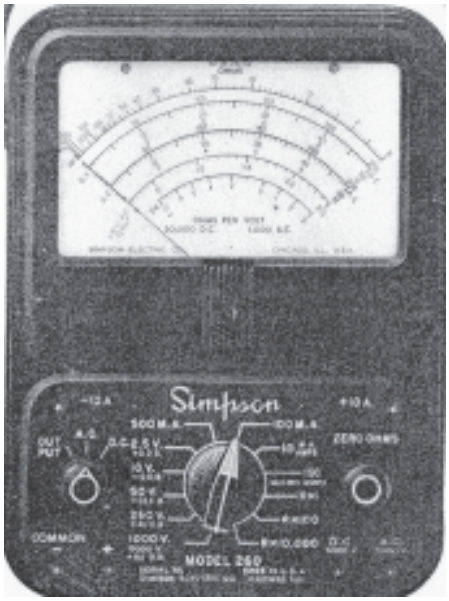

Fig. 2. Simpson model 260 VOM

sembled kit instruments than like the factory engineered and manufactured designs they really were.

Early attempts by some instrument manufacturers (e.g. Beede, Sterling, Hoyt, and Hickok) to design and make some of their own parts did result in a few instruments which showed some integrated design, but in most cases the parts were of such inferior quality that the motive seemed to be to save costs rather than to improve the quality of the instruments. Most companies still followed the conservative approach of using "only the best parts available on the market".

The Simpson 260 was a product of such philosophy. It wasn't pretty, or sleek, but it performed well and proved to be reliable, even in rough field service use. This was very important in a war-time military environment where the usual G.I. technician viewed almost everything around him as temporary and took little pains to "baby" any equipment. After all, it belonged to the Government and would be left behind when he "shipped out" to his next assignment, so who cared what got dented, cracked or fried?

Fortunately for the next user, the Simpson 260 was also easy to maintain, since most of the component parts were standard switches and resistors available on the open market. The only main parts which were uniquely Simpson's were the meter (in a separate case), and the molded Bakelite panel and back cover. Though the Plain-Jane look of the Simpson 260 became out-dated in the post war civilian repair market when more sophisticated looking instruments found favor, for many years after World War II, ex-military servicemen still valued the utility and war-proven reliability of this familiar and ubiquitous early Simpson VOM.

STRONGER MAGNETS

In the years prior to World War II (1938 to 1942), the Weston 697 and many other VOMs then in use shared a 1,000 Ohms/Volt sensitivity. Sixty years ago, the manufacture of these reliable, 1,000 Ohms/Volt full scale, jeweled instruments, which maintained calibration while surviving a service shop environment were considered to be a fine achievement. Therefore, this "high standard" of sensitivity was adopted as a United States Joint Army Navy (JAN) Standard to be used in testing all military electronic equipment. To help military personnel meet this objective, maintenance manuals were generated for all military equipment, giving the appropriate voltage readings when testing with voltmeters of 1000 Ohms/Volt.

During these early years, Weston, Simpson, Hickok, Triplett and other instrument makers used newly discovered magnetic alloys of tungsten, aluminum, cobalt, chrome, nickel, and iron to develop meters of 5,000, and later 10,000 Ohms/Volt, making a ten times increase in sensitivity over the military standard. By 1937 and 1938, multi-meters of 20,000, and 25,000 Ohms/Volt D.C. were being advertised by

Fig. 3. Weston model 564 Signal Corps Escutcheon

Fig. 4. Weston model 564 VOM

Triplett[4,5]; Supreme[6,7]; Hickok[8]; and Weston[9].

Since the military had a large investment in their 1,000 Ohms/Volt instruments, and in the training of personnel, and the documentation and maintenance manuals which gave voltage readings for 1000 Ohms/Volt instruments, they seemed to have no interest in changing their test instrument standard. Proof of this reluctance by the military is shown by the purchase of I-56 Test Sets in 1940, by the U.S. Army Signal Corps (Fig. 3), in which was included a Weston Model 564, 1000 Ohms/Volt D.C. multi-meter, (Fig. 4), supplied to meet government specifications. Ironically this meter, in spite of the "1000 Ohm per Volt" legend on the meter face, has a 10,000 Ohms/Volt meter movement

which had been deliberately shunted to draw ten times the current needed for full scale deflection, just to make the voltmeter comply with the Army's outmoded 1,000 Ohms/Volt specs. The Weston 564 circuit diagram confirms that the meter movement has a sensitivity of 100 µA full scale, (used no doubt, to enable the ohmmeter to measure high value resistances with only a 4.5 volt internal battery).

Not only is it absurd that a 10,000 Ohms/Volt meter had been debased, but at the time of this U.S. Army purchase, Weston had for over two years been offering their 20,000 Ohms/Volt Model 772 VOM[9] to civilian radio repairmen. Standardization had caused the military to lag by several years in the adoption of new technical advances. By contrast, civilian radio servicemen showed enthusiasm for the latest meter technology, such as was advertised by Triplett[10], and they quickly adopted meters that took only one-tenth of a mA or less from a radio circuit for a full scale voltage reading on their test meter. Civilian users were inclined to take good care of their instruments which were needed to earn a living, and they selected the testers which had a modern and professional look with an eye to impressing their customers.

Post war technology pushed further. Beautiful new analog D'Arsonoval moving coil meters of 20,000 to 50,000 Ohms/Volt appeared; some with custom molded Bakelite cases and integrated designs. These became the new standard of analog meter sensitivity, and among the examples which I found most admirable and interesting were the versions of the Triplett Model 630.

Fig. 5. Triplett model 630 VOM 1948 advertisement

THE TRIPLETT 630

If a proven instrument like the Simpson 260 didn't inspire the admiration and affection I had held for my early companion, the little compact, accurate and reliable Weston 697, why have the Triplett 630 types, which perform about the same function as the relatively plain Simpson 260, been singled out as the subject of special reporting?

The answer is that when I initiated a search for a meter to replace the Hickok 539-B/C tube tester meter, not only did the Triplett 630 meter movement meet the exacting requirements of the Hickok Tube Tester better than various other meters, but as I bought, and repaired, or disassembled various broken VOMs, I was impressed by two aspects of the Triplett 630 VOM designs: First, the Triplett VOMs embodied an integration of switching, insulation, housing, and ergonomics, which enhanced their appearance and ease of use above other instruments from the same era of design; Second, the sheer variety of capabilities offered in the Model 630 form amazed me; varying from a basic VOM to a combination VOM/VTVM and, also unbelievably, an exotic model of such extreme sensitivity, that it performed at near the level of an electrometer.

Fig. 6. Triplett model 630 VOM, circa 1958.

Fig. 7. Triplett model 630 VOM, circa 1970.

The first appearance of the Triplett 630 VOM, was in a two-page spread advertisement (Fig. 5) in *Radio News* of July, 1948, which announced and eulogized the 630 as the "Greatest Advance in V.O.M. History"[11]. It may not have been "the greatest", but there is no doubt in my mind that it was (and after more than 60 years of uninterrupted production, still is) a really fine instrument. A comparison of the outward appearance and electrical specifications of the early Triplett 630 VOM model

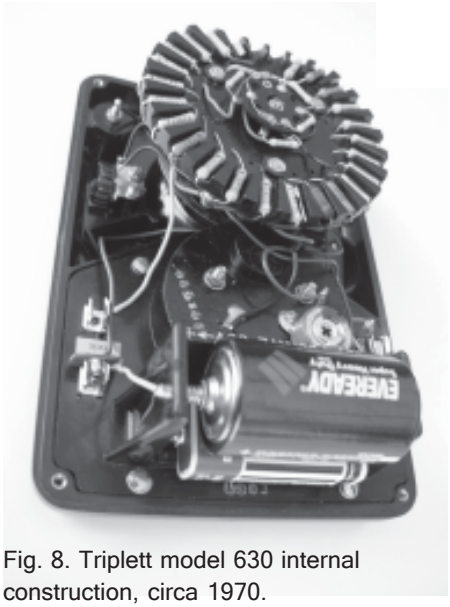

Fig. 8. Triplett model 630 internal construction, circa 1970.

made some 50 years ago (Serial 9,348, shown in Fig. 6), and of the twenty year old meter (Serial 234,282 shown in Fig. 7) confirms that they are almost identical to the present day Model 630, shown in the Triplett 2000-2001 catalog,[15]. The newer meters do sport a red Bakelite range selector bar, giving them a little distinction. In addition, the meter scale style has been simplified, by separating the red A.C. scales from the black D.C. scales, and giving each set their own color coded voltage numbers.

The earliest 630 VOM internal design used a compactly clustered, injection molded Bakelite piece, which combined the function of battery holder, and compartmented "revolver style" resistor carrier, in one piece which bolted to and became a part of the range switch (See Fig. 5). Apparently this very compact unit gave difficulty in either assembly, inspection, or rework, for in the later model, the battery holder was separated and moved to the back of the meter, and the resistor "revolver" was modified into a "carousel" with an open groove for each resistor (See Fig. 8). This likewise was bolted to the selector switch, making a single unit.

The meter movement is housed in a special chamber of the front Bakelite molded chassis/front panel which also houses the integrally designed master range switch and bar knob. All switch contacts are silver clad, clamped and enclosed in tiers around the switch body, enclosing the switch contacts in a protected "box", free from dirt, and safe from mechanical damage during assembly or repair (Fig. 5). The custom designed Bakelite chassis/panel also integrates the battery housing and contacts inside the panel, with molded-in threaded brass inserts for the four 6-32 screws which hold the back housing to the front chassis. The case completely encloses all components and provides a high voltage insulation safety barrier.

Fig. 7 shows all nineteen measurement ranges switchable by the 20 position master range switch on the front of the instrument. The voltage ranges cover from 3 Volts to 1,200 Volts for both A.C. and D.C. in 5 ranges each. A sixth range of 6,000 Volts for either A.C. or D.C. is achieved by plugging in a special cable containing an additional voltage multiplier resistor inside the high voltage probe. There are also five D.C. current ranges from 60 µA to 12 A.

Fig. 9. Triplett leather meter cases, models 639 and 639-N.

Resistance measurements are all read on the same Ohms scale with direct readings from 0 to 1,000 Ohms, (midscale reading = 4). The four switched ranges give multipliers from "X 1" to "X 100,000". This extraordinarily wide range of resistance measurements is possible only because of the high sensitivity of the meter, (50 µA), and the use of a 30 Volt "cartridge" battery (Burgess Type U20, or equivalent) in series with the 1.5 Volt "D" cell in the ohmmeter circuits.

The single switch control simplicity of the Triplett 630 is readily apparent, just by looking at it. The operation lives up to its promise of ease of use, and the accuracy of measurement ranks with some of the finest instruments made. It has been much imitated, and that says a lot about its quality and acceptance.

DRESSING UP THE BASIC 630

Reviewing many broken and dysfunctional Triplett 630 meters has shown that the part most vulnerable to handling damage is the outside Bakelite case. Although the back cover was designed with ample 1/4 inch thick walls, evidence shows that it is susceptible to being cracked by a violent drop, or impact with harder objects. The problem was addressed by Triplett, first with several styles of protective leather carrying cases: Model 639 and Model 639-N (Fig. 9)

Fig. 10. Triplett model 630-D VOM (KS-14510-15)

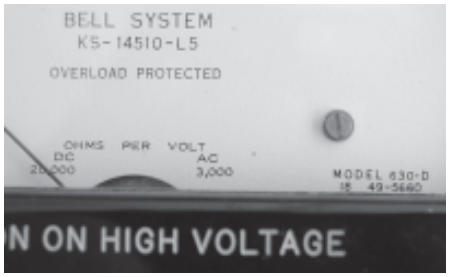

Fig. 11. Triplett model 630-D meter face detail.

Fig. 13. Triplett model 630-D case.

and by the military with a tough ugly molded fiberglass back which replaced the Bakelite housing. The leather cases look really nice, and offer defense for the meters from most types of damage, but the protection comes at the price of the inconvenience of putting the meter in and out of the case whenever it is used. The snap-front Model 639-N case provides a front opening so the meter can be accessed and used while in the protective case, but even that isn't too easy because the case tends to close itself unless held open. I like to store the meters in a case but in use, I prefer the uncovered meter taking extra care to not damage it.

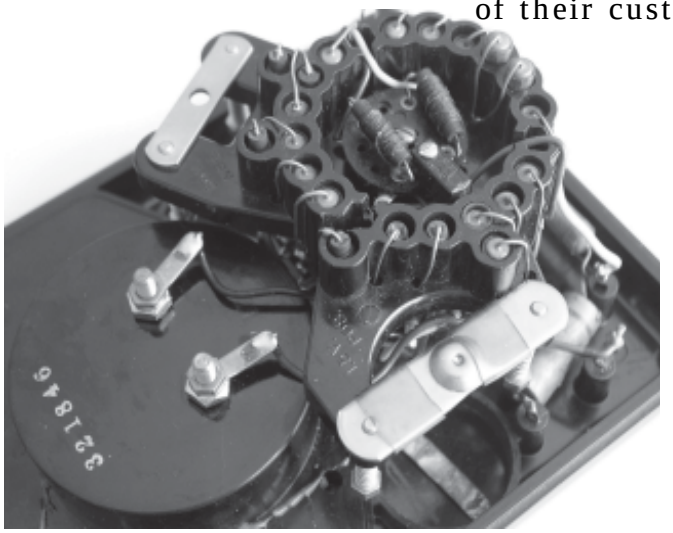

Fig. 12. Triplett model 630-D internal construction.

Triplett offered many variations of the 630 design to meet the specific needs of some of their customers. Fig. 10 shows the Model 630-D, a basic meter made for the Bell Telephone system and given an in-house Bell identification, KS-14510-L5. This meter is designed with test jacks having a re-entrant insulated collar molded around each probe "safety test jack" preventing contact with the metal plugs while inserting or unplugging the test leads. This safety feature protects both the person doing the testing and the equipment being tested. Fig. 11

Fig. 14. Triplett model 630-A laboratory grade VOM.

A 1957 advertisement[12] reminded users that Triplett made a premium meter (announced in 1950), the Model 630-A (Fig. 14), having all 1/2% precision resistors, hand calibrated scales, and an anti-parallax mirrored meter face for high accuracy laboratory use.

Early in 1955, newer versions of the 630 such as the 630-APL and 630-NA, were introduced with a restyled clear unbreakable plastic "wrap-around" meter front, which gives the 630 instruments an entirely distinctive appearance. No previous models were changed, so only newly released instruments appeared in the new design.

A wide variety of 630 models is portrayed in a 1959 Radio News advertisement[13], but since the 630-M (described below) is not shown, there may be other 630 models of which I am unaware. Almost all of the Triplett 630 meters seem to

also shows that the 630-D has 3,000 Ohm/Volt A.C. sensitivity, which is lower than the normal 5,000 Ohms/Volt A.C. rating of the 630 VOM. Another distinction of the 630-D meter is the use of the original enclosed "revolver style" resistor holder (Fig. 12), instead of the open grooved "carousel" style resistor mount. The meter was provided with a 639 carrying case embossed with the Bell designation: KS-14510-L5, on the top of the leather case (Fig. 13).

Fig. 15. Simpson model 265 VOM, circa 1965

have the same 20,000 Ohms/Volt D.C. meter movement, and 5,000 Ohms/Volt A.C. rectifier circuitry, with only a few notable exceptions.

SIMPSON FIGHTS BACK

It should be noted that by the 1960s, Simpson had also redesigned their old reliable Model 260 several times. Figs. 15, and 16 show one of their later Model 265 VOMs of circa 1965. Most of the improvements emulate Triplett's integrated design, and as such I must praise the quality and attractiveness of the Simpson 265 VOM. The multiplier resistors are mounted in a specially molded oval "revolver" style similar to Triplett's early design. All batteries are nested in special compartments molded in the one piece instrument panel, and the front panel integrated assembly even includes a specially enclosed current transformer to provide for high A.C. ranges of 0.12, 1.2, and 12 A.C. Amperes. Still, Simpson used a separately manufactured wafer style switch, and mounted the separately cased meter as a component on the front of the panel, making the instrument look a little dated and boxy. This is regrettable, as the meter itself is a very modern *taut band* design of 20,000 Ohms/Volt D.C., and 5,000 Ohms/Volt A.C. with quality and accuracy equal to the Triplett 630 meter. The only aspect for which the Simpson 265 may possibly be faulted is the form factor, which of course is directly related to the degree of integration of the functions into the housing. The meter and the switch control protrude from the face of the instrument creating an uneven front surface, hardly a problem in most test environments.

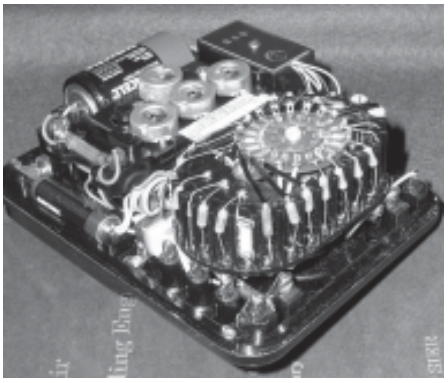

Fig. 16. Simpson model 265 VOM internal construction.

A 630 FAILING

The 630 voltmeter is like a butterfly. The circuit it measures is scarcely affected by its touch, as the loading is often above a Megohm. The meter fails in only one area of radio

Triplett 630 VOM

Fig. 17. Triplett model 631 VOM/VTVM.

To meet this challenge, the high input impedance VTVM came out of the laboratory and onto the service bench. Many companies offered VTVMs of widely varying complexity and stability, so they were initially viewed as either too fussy or too expensive. In 1955, the Simpson Instrument Company was offering a balanced twin-tube VTVM (their Model 266) which embodied 52 resistors, of which 16 were expensive precision and 12 were very expensive, high resistance, precision carbon film types (three 20 Megohms, three 80 Megohms, and one each 5, 10, 30, 38, 40, and 66 Megohms).

servicing measurement. That is in low D.C. voltage measurements in the Automatic Frequency Control (AFC), or Automatic Gain Control (AGC), grid bias circuits of radio receivers. When these multi-Megohm circuits are tested with a voltmeter of only 60,000 Ohms (20,000 Ohms/Volt on a 3 Volt range), when it comes to disturbing the circuit voltages, and giving erroneous readings, the Triplett 630 meter (and other 20,000 Ohms/Volt meters) can look more like a water buffalo than a butterfly.

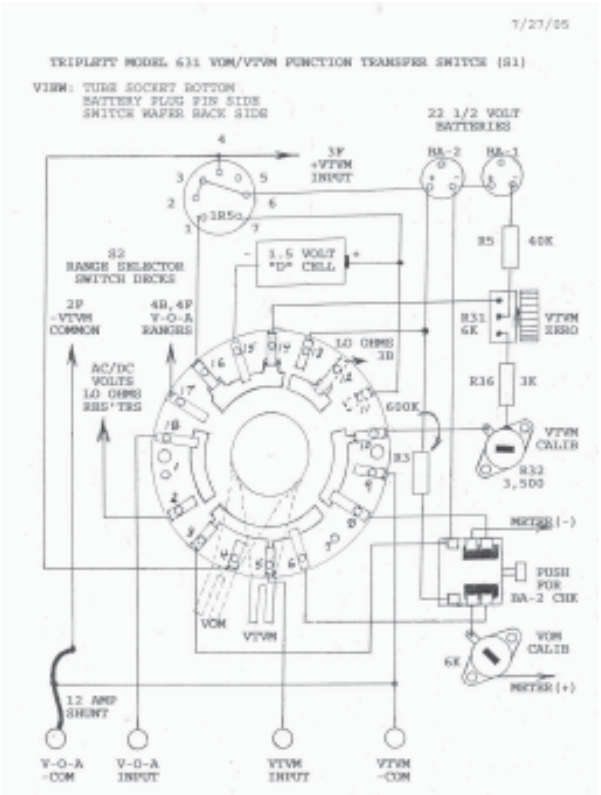

Fig. 18. Triplett model 631 VOM to VTVM transfer switch wiring.

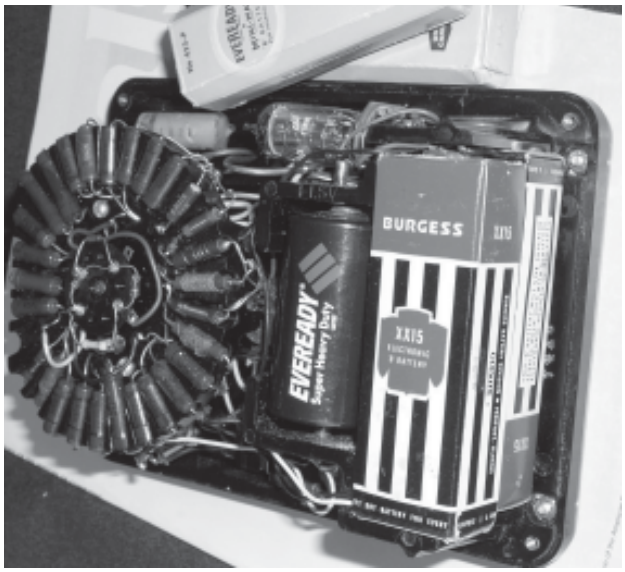

Fig. 19. Triplett model 631 VOM/VTVM internal construction

The Simpson 266 instrument had an input resistance of 50 Megohms on all ranges.

At about the same time, RCA offered their low cost, balanced twin tube "VoltOhmyst" VTVM, with only three precision carbon film resistors of over 1 Megohm in the input, (one each 7, 2, and 1 Megohm) giving a modest eleven Megohm fixed input resistance on all ranges. This resistance was high enough to enable measurement of AGC and AFC voltages on radio receivers without disabling the circuit being measured.

Triplett and many other manufacturers, copied the eleven Megohm input for their versions of the VTVM, attracted no doubt by the small number of high priced, precision, high value resistors required.

THE TRIPLETT 631

Triplett design engineers must have decided that they couldn't beat the new VTVMs, so instead of fighting them, they joined them. I was delighted to find that the Triplett Model 631 VOM/VTVM (Fig. 17), which looks almost identical to other versions of the 630 Triplett VOMs, embodies not only an excellent VOM, but it also contains a four range VTVM[14]. To use the VTVM, the master range switch is first turned to one of the four VTVM D.C. voltage ranges, then a slide switch below the range switch is moved to the left, making the appropriate circuit changes (See Fig. 18) to turn on an internal filament type tube converting the meter into a D.C. VTVM with an input impedance of 11 Megohms.

Fig. 19 shows the internal parts arrangement of the 631 VOM/ VTVM. The 631 VTVM uses a custom molded Bakelite "carousel" similar to, but slightly larger than the one used in the 630 VOM. Both of the instruments use 1% resistors throughout, either wire wound or carbon film; 25 resisters in the 630 VOM, and 27 in the 631 VTVM. The most noticeable differences inside the 631 VTVM are the presence of the 1R5 vacuum tube and two 22 1/2 Volt 'B' batteries. The two battery types shown are obsolete and sadly aren't now available.

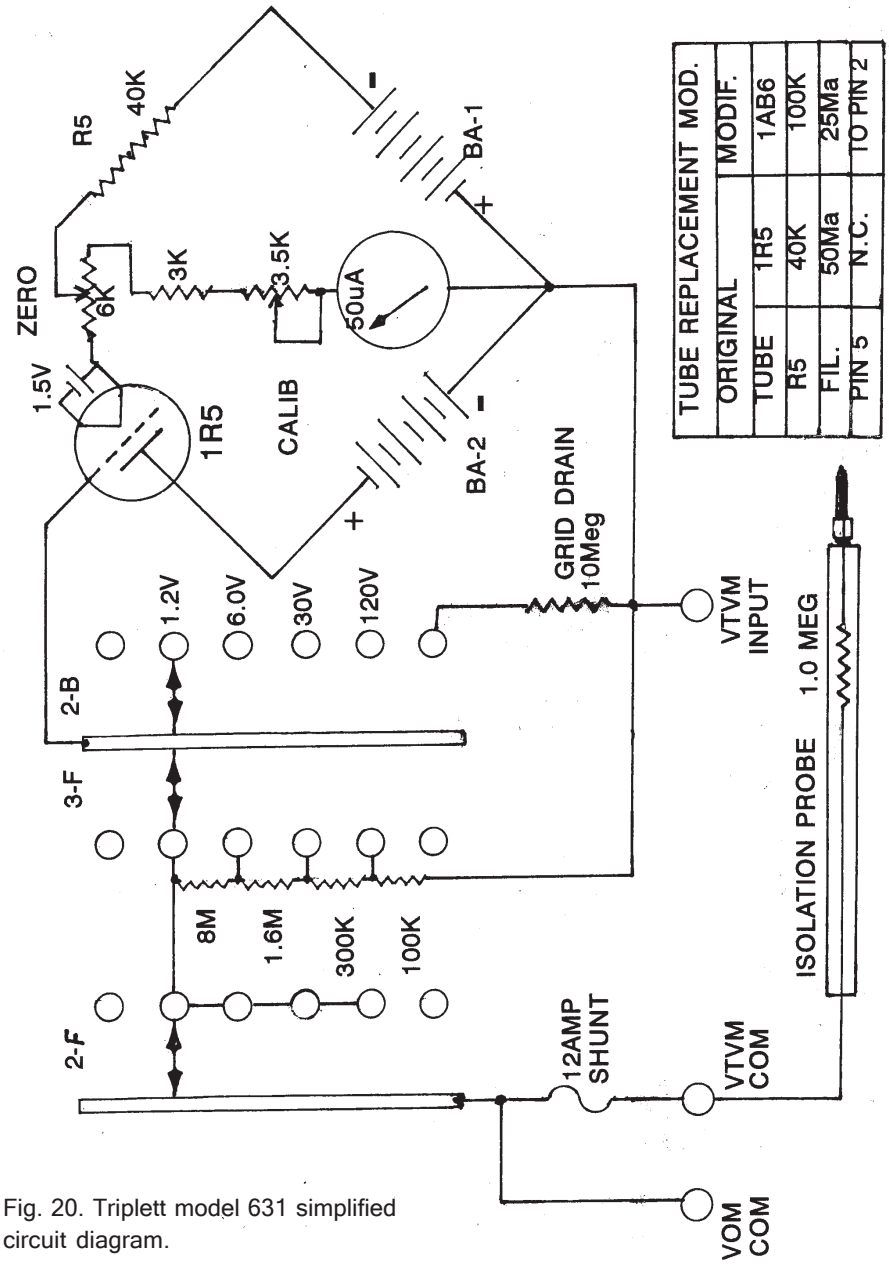

Fig. 20. Triplett model 631 simplified circuit diagram.

From the front the four special VTVM ranges are conspicuous above the VOM/VTVM transfer switch, but the meter face has a hardly noticeable small sign to indicate that the same scales are used for both the VTVM and the VOM. It should be noted that special VTVM leads are provided which plug into VTVM banana jacks on the left side of the front panel. These test leads are not interchangeable with the regular VOM test leads, for the black "COM" test probe contains a 1% one Megohm isolation re-

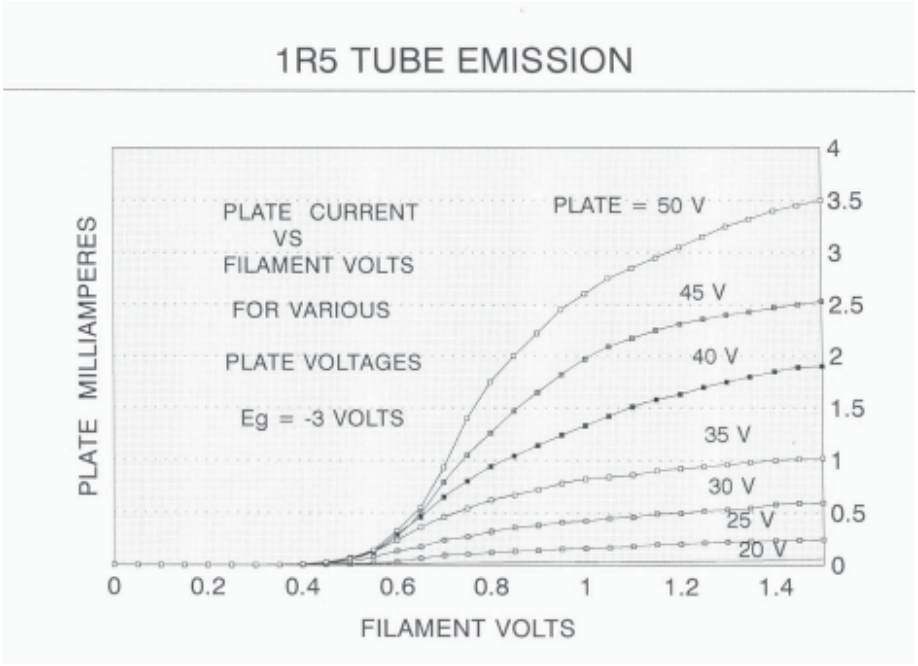

Fig. 21. 1R5 tube emission vs. filament volts

sistor which is part of the input circuit for the VTVM. No doubt if the Triplett 631 loses its VTVM test leads, or is used by an owner who is unfamiliar with the instrument, the user may by mis-

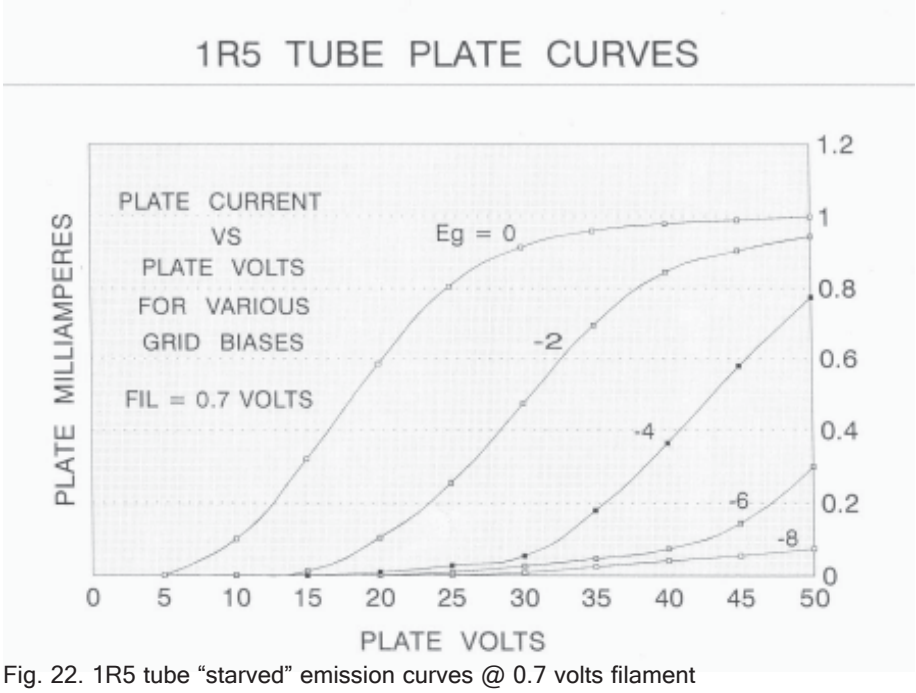

Fig. 22. 1R5 tube “starved” emission curves @ 0.7 volts filament

take use the regular VOM test leads plugged into the VTVM jacks. This gives inaccurate voltage readings up to 10% too high.

Fig. 20 shows a simplified schematic of the Triplett 631 VTVM (without the confusion of all the switches between VOM and VTVM use). In the 631 VTVM design, a bridge balances R5, a precision resistor arm, against the plate resistance of a 1R5 vacuum tube. Note that even though the tube circuit appears upside down, that the tube operates as a cathode follower, giving negative feedback to changes and non-linearity in tube gain. Unfortunately the resistive bridge circuit is balanced against a "fixed" voltage taken from the center tap of the "B" batteries so as the batteries drift in voltage, the meter requires a "zero" reset from time to time.

One startling characteristic of the unbalanced "half-bridge" of the 631 is that the meter is subject to a "meter slam" of nine times full scale current overload if the VTVM is switched fully on without first letting the tube filament warm up. A simple calculation shows that the 50 µA meter is subjected to 450 µA; (22 1/2 volts applied across the 40K Ohm bridge arm in series with about 10K meter resistance). Triplett provides a center "warm up" position on the VTVM switch, but in haste, I have forgotten to pause at the half way click and the results are truly alarming. Despite its idiosyncrasies, the vacuum tube circuit performs well, making the Triplett 631 a really versatile and valuable meter for the radio service bench.

IMPROVING THE TRIPLETT 631

When I first examined the 631 VTVM, I was surprised to see a pentagrid converter tube, the 1R5, being used as a triode in the circuit (Fig. 20). The basic VTVM circuit has almost a stark simplicity which I wrongly thought might be a sign of low budget engineering and design. Was Triplett motivated by long battery life, by low cost or by easy availability of parts? The enigma was soon resolved when I discovered a footnote in the RCA tube manual showing that the 1R5 has a transconductance (Gm) of 1400 micromhos/volt as a triode[15]. Comparing this Gm to the 900 for the 1U4, and lesser values for other 50 mA filament miniature tubes, it seems likely that the 1R5 was selected for its high Gm, and low filament power; 1.5 Volts at 50 mA. It also seemed reasonable that to save power, only one tube was used in the circuit.

With the present day choice of new 25 mA filament tubes, why not use a two tube balanced bridge to eliminate the "meter slam"? So without much thought, and as a test, I replaced the 40,000 Ohm resistive arm of the existing bridge circuit with a second 1R5. This would provide a balanced warm up, and cancellation of tube emission changes. It sounded so easy, and it wasn't hard to wire in.

What a disaster!! The instrument acted like an unbridled rodeo bronco, slamming

the meter from side to side with just the slightest movement of the tubes in their sockets. The two tube 1R5 bridge circuit carried so much plate current in each tube, that just the smallest differential in filament heating caused by moving the tubes in their sockets, though small in percentage, unbalanced the bridge enough to drive the 50 µA meter into wild deflections.

What I hadn't factored in was the original design over-kill of a plate current ten times the full scale meter deflection. In connecting the two tube filaments together, the meter had to be moved to the plate circuit where direct negative feedback was not possible. The result was an amplified meter deflection which followed every small difference in the operating conditions of the two tubes.

At this point I took time to rethink the problem. Here is an instrument with 1.2 Volts full scale on its most sensitive range, driving a meter of 50 µA full scale. The needed Gm is less than 50 µA/Volt, not the 1400 represented by the fully powered 1R5s. Measurement of the 1R5 characteristics (Fig. 21) showed that it has much larger plate current than is advisable, and gives usable emission even down to a filament voltage of only 0.7 Volts (See Fig 22).

Review of the approach taken by RCA on their Junior VoltOhmyst, No 165, showed that the 6K6 filament voltage was reduced from the rated 6.3 down to 5.7 Volts to minimize grid current and grid contact voltage[16]. Other design criteria were to limit the tube plate current to values only several times the full scale meter current during overload, and the use of a large value common bias resis-

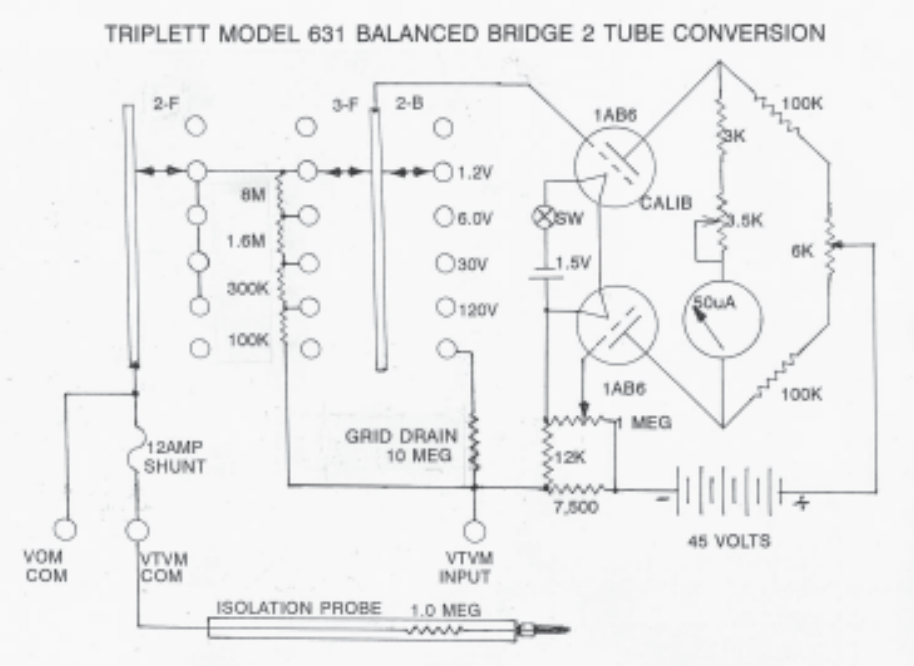

Fig. 23. Triplett model 631 balanced bridge using two 1AB6 tubes

tor in the cathode return to improve the stability of the circuit.

Following these guides led to a modified design of the 631 with the two 1R5 tubes (1.5 Volts each) heated in series on the 1.5 Volt "D" cell. This reduced the 50 mA heater current to 32 mA and guaranteed both tube filaments would always be equally heated as the filament current varied from circuit resistance or battery voltage changes. Increased plate and cathode resisters gave "starved" plate current in each tube of about 90 µA and the maximum meter current was limited to less than 200 µA.

The new configuration was beautifully behaved. It was stable and reproduced its readings with almost no turn-on drifts. All looked good for the new design until I carefully calibrated the meter response across the entire scale. It was possible to get accurate calibrations at zero and full scale, but the deviations in other areas of the scale were of the order of 3% to 6%, unacceptable for an otherwise accurate and coherent instrument.

I had already arbitrarily selected and ordered a number of 1AB6/DK96 tubes which had almost the same base connections as the 1R5, and could be used with a minimum of base wiring change. The 1AB6 is a 1.5 Volt 25 mA filament tube using only half of the 1R5 current.

Two 1AB6 tubes take no more filament current than a single 1R5, and provide much more emission than is needed for the starved circuit. With the exception of one grid connection the 1AB6 was interchangeable

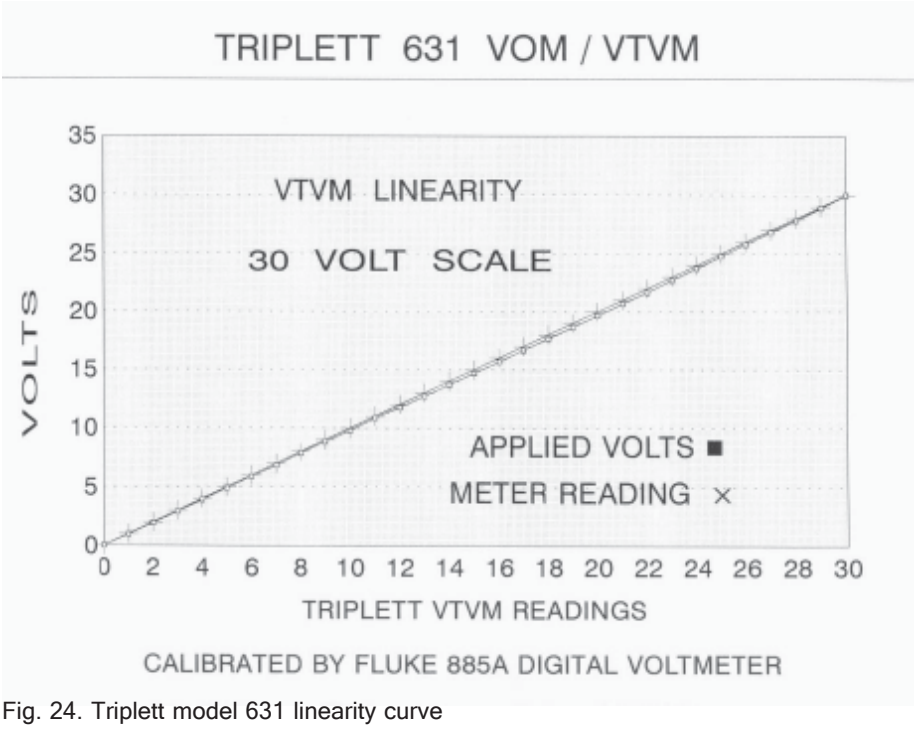

Fig. 24. Triplett model 631 linearity curve

with the 1R5, so I kept the series filament circuit and tried the new tubes. After adjusting the bias and meter padder resistors, the VTVM was soon back in business, drawing only 18 mA of filament current and approximately 100 µA of B+ current. Fig. 23 shows the modified circuit for the 631 VTVM using two 1AB6 tubes in a "starved" mode for both the filaments and the plate circuit. Once again, I was able to largely cancel the two tubes non-linear voltage/current curves, but in the end I found the calibration non-linearities unacceptable so I reluctantly abandoned this design also.

I concluded that in the "starved" current operation, with the relatively high 45 Volt plate voltage, the pentagrid converter tubes had transfer curves with several inflexions so only partial cancellation of these effects was possible. At this point, the question might have arisen, Why use 45 Volts? The answer was unarguable. Forty-five volts was needed by the "X 1000" high Ohms range of the 631 VOM.

As expected, all two-tube circuits eliminated the meter slam at turn-on, and reduced the filament current below the 50 mA used by the single 1R5. They had also reduced plate current to below 200 µA, but none of them consistently gave the smooth linearity shown by the original 1R5 circuit (Fig. 24). I had gained a new respect for the deceptively simple circuit of the Triplett 631 VTVM as a cathode follower type of amplifier, and for the art of getting good results with a minimum of parts.

Of all the approaches to improve the Triplett 630 VTVM's one tube circuit, the most successful was the substitution of a 1AB6 tube, which used only 25 mA of filament current to replace the 50 mA 1R5 tube. This wasn't an option for the original designers, since 25 mA filament tubes were not available until after the Triplett 631 meter was released. To use the 1AB6, pin 5 of the socket (grid 4) must be connected to pin 2 (plate) with all of the other grids.

NOTE: Once this connection is made, do not re-insert a 1R5 into the socket for the 1R5 tube has an internal connection which shorts the socket from plate (pin 5) to filament (pin 1).

Since the 1AB6 plate resistance is higher than that of the 1R5, the VTVM bridge needed to be rebalanced by increasing the resistance of the comparison load resistor R5. Tests showed that almost complete correction of the 1AB6 tube transfer non-linearity was possible by the proper selection of the bridge arm resistance. The optimum value of R5 was determined to be 63K Ohms, which was made by splicing a 23K resistor in series with the 40K bridge arm in the negative lead from BA-2..

On 0 to full scale calibrations, the meter return position was within a needle width, which translates to less than 0.25%. It was beyond expectations when final adjustment of R5 and the operating bias achieved almost perfect calibration linearity across the entire meter scale.

Since 23K is not a standard value, a resister within 1% of the value was selected from 10% resisters of 22K. Finally R32, the calibration rheostat was adjusted to set the meter full scale response to match the full range voltage applied to the 1AB6 input.

At this point, I stopped my improvement efforts. Thanks to the faster warm-up of the 1AB6 filament, and the increased bridge arm resistance, there no longer was a meter slam when the VTVM was turned on without allowing warm-up time. Only deliberate fast switching can make the meter needle reach the end of the scale. The usual response of a quick VTVM turn-on is a half-scale upswing of the meter, followed by an immediate damped settling toward zero. This response also reflects the greatly reduced operating currents. The filament current measures 22 mA, and the plate current measures about 250 µA. These values are about half of the original battery drains of 50 mA and 450 µA respectively by the 1R5 tube.

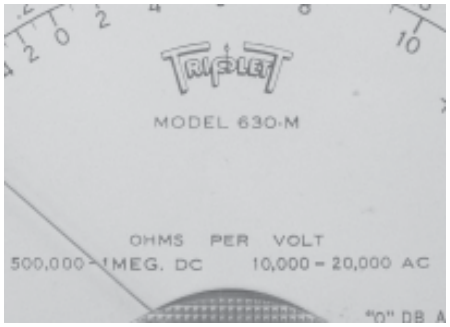

Fig. 26. Triplett model 630-M meter face

Fig. 25. Triplett model 630-M VOM (One Megohm/Volt)

The Triplett 631 VOM/VTVM originally used two Burgess Type XX15, or Eveready Type 425-P, 22.5 Volt batteries (See Fig. 19). The Burgess Battery Company was taken over by Ray-O-Vac and Union Carbide sold Eveready to Ralston-Purina and apparently neither successor company finds it profitable to manufacture these batteries, nor are there any similar ones on the market. My initial batteries were made of 30 Type AAA cells soldered in series, and held in a three-cell by ten-cell fold-up cardboard retainer. The process of making these batteries was laborious, and a few cells were ruined by the soldering.

In spite of their limited life prospect, two small Eveready No. 412 cartridge type 22.5 Volt batteries were clipped into a plastic holder made for two C cells. This fit easily in the BA-1 and BA-2 battery space, and was held in place by Velcro. The Triplett Model 631 VOM/VTVM is especially handy when a cordless VTVM is needed for

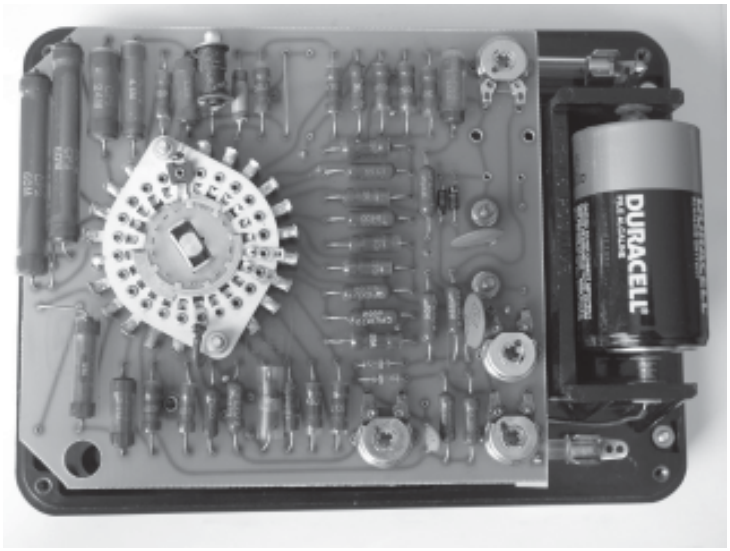

Fig. 27. Triplett model 630-M internal construction

low voltage measurements. If Triplett's best achievement had been the Model 631 VOM/VTVM, they would deserve praise for the utility of their instruments and admiration for the ingenuity of the designs they have made. But I was delighted to find that Triplett had exceeded their VOM/VTVM achievement with another design of even more sophistication and greater convenience and utility.

THE TRIPLETT 630-M

One of my vintage analog instrument purchases was a VOM that looked at first glance just like another 630 VOM, except it was labeled Triplett 630-M (See Fig. 25). I selected it from a bin of damaged instruments because the case was perfect, and the leather handle was in excellent condition. When I finally took the time to read the face of the meter (Fig. 26), I was incredulous. The D.C. sensitivity stated on the face of the meter was "One Megohm per Volt"! This VOM had a full scale deflection of just ONE µA!

I knew that Sensitive Research Instrument Corporation of New York had offered 1,000,000 Ohms/Volt, D.C. Voltmeters in their 1956 Catalog, and advertised them in the Review of Scientific Instruments[17]. But these were large, heavy, horizontal use only, laboratory grade meters, equipped with "diamond pivots", the exclusively expensive hallmark of Sensitive Research instruments. Although their meters had six voltage ranges, the maximum range of the basic $393.00 meter was 0-10 Volts, with "Higher voltage ranges available, correspondence solicited". At such 1956 prices, I didn't need to know the cost of higher voltage ranges to dismiss them for radio servicing.

My desire to fix the Triplett 630-M didn't override my desire to preserve it. The first thing I did to protect the meter from damage was to short the meter movement at its terminals. A manual from Dr. Alvin Bernard in Florida and some diagnostic tests showed that a precision wire wound resistor

was wholly missing, and a second resistor had one end unsoldered. After winding and calibrating a new resistor, resoldering those joints which looked suspect, and un-shorting the meter, it worked perfectly. The manual states that the meter movement is a taut band type and as such has no frictional elements.

Apparently, faced with the limitations of phenolic insulation, Triplett had to abandon their Bakelite resistor carousel. They mounted all multipliers on a high grade glass-epoxy printed circuit board, and used a special high resistance wafer deck to switch all of the voltage multiplier resistors, (See Fig. 27). This led to the use of an all wafer switch, and a shift to printed circuit assembly techniques quite different from the original injection molded unitized assembly for the Triplett 630 VOM.

There is one feature of the 630-M which is shared with two other of the 630 series meters, the V-A/2 switch. This switched reduction in meter sensitivity, which enabled twice the voltage to be measured with the same voltage multipliers, (at twice the current) and doubtless saved resistor costs but denied the user the full instrument sensitivity on half of the ranges. I found this clever cost saving idea objectionable when it was encountered in the one Megohm/Volt Model 630-M, where costs were probably critical. But such a ruse in a medium cost instrument seemed egregious and even unethical.

The circuit diagram (Fig. 28) shows that Triplett did what they could to keep the number of high value multiplier resistors down to two at 60 Megohms on the high ranges, and lesser values on the lower ranges. This was accomplished in three ways.

First, the meter is provided with a switchable one µA shunt R42 which normally is left across the meter, for all ranges except the 1200/600 volt range, so for the ranges as marked on the switch, the instrument is really a 2 µAmp meter, with multipliers for 500,000 Ohms/Volt. The saving of using only one half the resistance for every voltage multiplier resistor isn't great for low voltage ranges, but for the ranges over 100 Volts, the saving in high value precision resistors is significant. The penalty to the user is that the meter gives only half the sensitivity which Triplett advertises, and which the meter movement could provide.

Second, switching the meter to the Volts/2 position restores the meter's one Megohm per volt sensitivity, but then the meter can only measure one-half the voltage shown on each range. (i.e., all the voltage multipliers are half the resistance required for the marked voltage ranges). This is the alternative penalty Triplett has imposed on the user by making every resistor in the meter to be half as large as would be normally required for a meter of unimpaired sensitivity.

Third, on the 1200 Volt range, a three µA shunt R7 is switched in across the 3 Volt range, making the meter read at four µA (250,000 Ohms/Volt) for the 600 Volt range. When switched to Volts/2 it operates

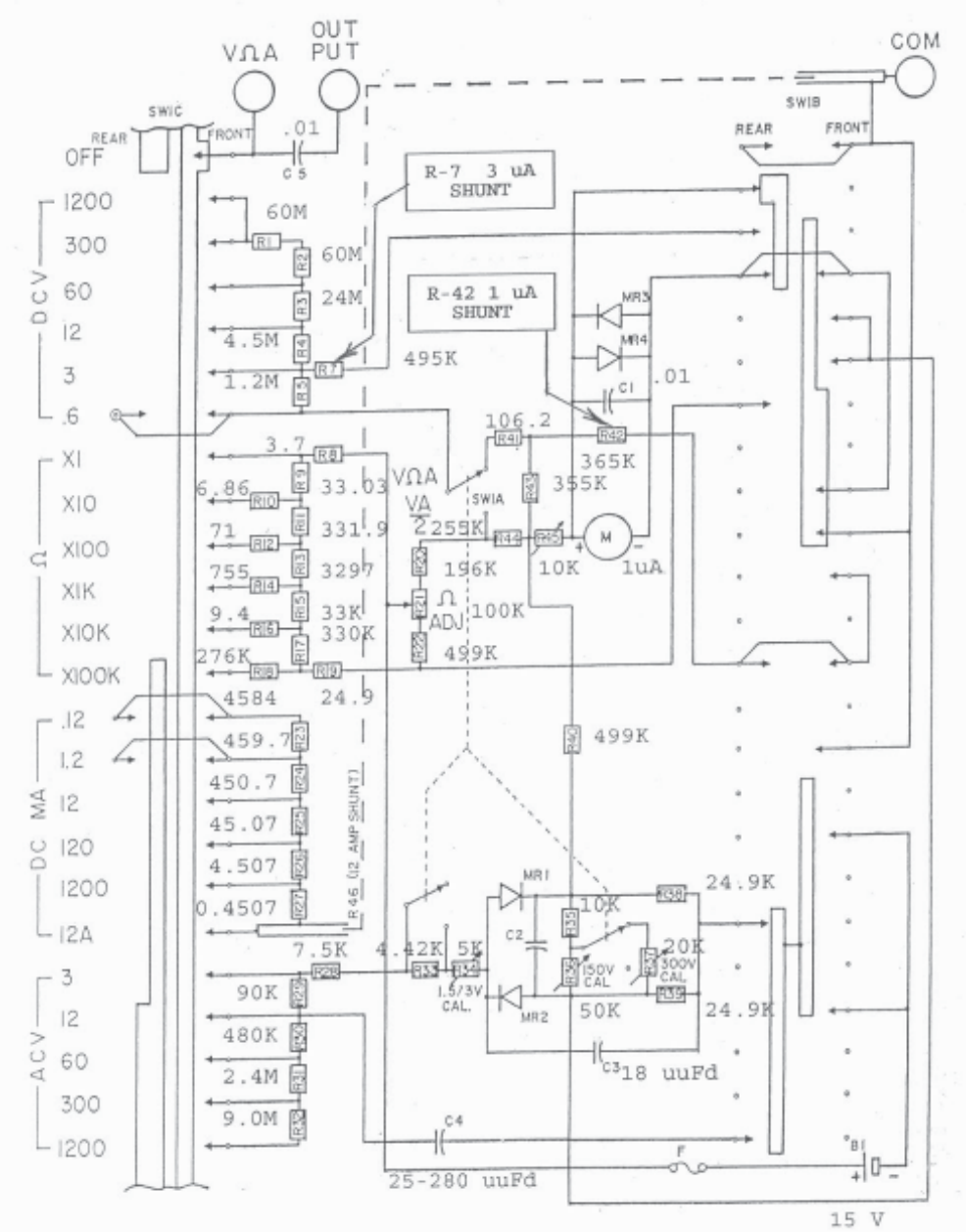

Fig. 28. Triplett Model 630-M Volt Ohm Milliammeter Circuit Diagram

at eight µA (125,000 Ohms/ Volt) for the 1200 Volt range.This single switch quadruples the voltage scale for all the other resistors in the multiplier string, so the previous 150 volt range becomes a 600 Volt range at 1/4 the sensitivity. Thus, no added series multiplier resistor is needed on the high voltage range, and the 600/1200 Volt position is hard wired to the next lower 150/300 Volt selector switch tap. This reduction

of sensitivity on the high voltage range avoids using 1200 Megohms of multipliers, at a considerable savings in cost, but a serious loss of sensitivity.

I shouldn't cavil with the design of such an incredible instrument, but I find myself strongly disaffected by a design which makes the user choose between half the possible sensitivity, or half the scale range of Volts. I was perplexed by this apparent lapse in engineering philosophy, so I looked for any precedence for this marketing orientation. Sure enough in May, 1955, Triplett had brought out a Model 630-NA VOM advertised as "ALL in ONE", whatever that means[18]. Its claim to greatness was that it had 70 ranges. Closer scrutiny revealed that it was simply the standard 630 VOM with a switch concentric with the range switch which doubled the number of ranges by shunting the meter movement down to half sensitivity. This makes all ranges require twice the voltage for full scale deflection, while requiring twice the current (1/2 the sensitivity).

It is interesting to speculate that if this meter had not been made, with it's special concentric V-A/2 switch design, the Model 631 VOM/VTVM might not have been realized, for it came out in July, 1956, a year after the 630-NA, using an ingenious switch which borrowed directly from the design of the V-A/2 switch in the 630-NA.

It must be said that the idea of a V-A/2 switch had been around Triplett for the prior seven years, since April, 1948 when the pre-630 multimeter, the Model 625-NA was advertised[19]. This VOM was an unattractive Simpson 260 look-alike, with two switches with bar knobs, and an Ohms adjuster protruding from the front panel. The 625-NA had six D.C. voltage ranges at 20,000 Ohms/Volt, which was doubled to six more ranges at 10,000 Ohms/Volt, by a shunt controlled Volts/2 switch. It also offered 10,000 Ohms/Volt A.C. in six ranges. I just can't appreciate this approach to voltmeter implementation, and I find it regrettable that Triplett chose to use it in their otherwise irreproachably designed fine instruments.

Even though it lacks the "purity" of an "all Megohm/volt" design, the 630-M VOM is stable, accurate, and of remarkably high impedance on all ranges. Even so, it should be noted that on the 1.5 and 6 volt (3V/2 and 12V/2) ranges, that the input resistance of the 630-M one Megohm/Volt meter is 1.5 Megohm and 6 Megohm respectively, which is lower than the 11 Megohm input of the 631 VOM/VTVM. So the 630-M does not answer all needs though it sure answers a lot of them.

In the future it would be nice to disable the switched shunts, and add high voltage multipliers to extend the meter into the high voltage ranges at full sensitivity. This would require obtaining at least 900 Megohms of precision resistors, and assuring that the surface leakage of the insulators on which the parts are mounted doesn't defeat the accuracy of the precision multiplier resistors.

The Triplett instruments can't match the 0.25% accuracy of the fine laboratory instruments from Leeds and Northrup, Sensitive Research, Beckman Instruments, etc. but all multiplier resistors in the Triplett 630, and 631 are specified to be within 1% of their designated values. The 630-M has no tolerance shown on the resistor values, but the overall accuracy is specified at 1 1/2% for D.C. measurements. This is better than needed for usual radio uses.

One of the happiest features of the 630-M meter is the fact that only a single D cell battery is sufficient for an extremely wide range of ohm meter scales. On the X10,000 ohm range, a mid-scale reading of 400,000 Ohms extends on to useful readings of 100 Megohms. This is such an improvement over the two 22 1/2 Volt B batteries and a D cell used in the Triplett 631 VTVM, that again, my affections have wavered, this time toward the incredible one Megohm/Volt Triplett 630-M.

IMPROVING THE TRIPLETT 630-M ?

I no longer ignore those old broken cased Bakelite VOMs at flea markets, for they may contain one of those 1% carbon film, 80 Megohm resistors needed to help upgrade the Triplett 630-M on 1200 Volts to a true Megohm/Volt sensitivity. (I am still incredulous!)

As a practical matter, few meters have high precision carbon film resistors above 20 to 30 Megohms, so to add another 900 Megohms, might require the collection and mounting of about 30 resistors. In the Triplett 630-M there is about 0.625 inches of space over the existing circuit board in which a piggy-back board could be mounted with the required resistors. To correct the existing voltage dividers to make the meter a fully 1 µAmp meter on all D.C. ranges, would require the replacement of the five existing multiplier resistors. This would be a daunting task, since the resistors needed are 1% precision values of 2.4 Meg, 9 Meg, 48 Meg, 240 Meg, plus 900 Meg for the top range. Such an extensive modification would require special parts acquisition, and it would leave the meter with a useless function of the VA/2 switch on D.C. Volts. It is well to move slowly when attempting to improve a design made by Triplett engineers.

A TRIPLETT 630 UPDATE

Innovations by Triplett, including the taut band seem to have out-matched Jewell, Weston, Hickok, and other meter manufacturers including Simpson's taut band, and even challenges the Sensitive Research diamond jeweled meters. Now the analog meters have largely been replaced by autoranging digitizers and liquid crystal displays, but those trembling meter pointers still impart a sense of the currents driving them which is totally unseen on a digital readout.

Since it was necessary to buy some 22 1/2 Volt B batteries for the Triplett 631 VOM/VTVM, I spent some unaccustomed time in a retail, new parts electronics store. After securing several batteries (by back-order

only, since high voltage batteries are seldom carried in stock), I picked up a new 2000/2001 Triplett Catalog[20].

Unbelievably, the Model 630 and others of its series are still being sold! The original 60 year old glass windowed Model 630 is still offered with a sensitivity of 20,000 Ohms/Volt on D.C., and 5,000 Ohms/Volt on A.C. The only meter offered with higher sensitivity, the 630-NS is one fifth as sensitive as the 630-M, with 200,000 Ohms/Volt on D.C., and 20,000 Ohms/Volt on A.C. Regrettably, no 631 VOM/VTVM or any equivalent is available, but a pocket sized version of the 630 Meter; the Model 310, first advertised in Jan, 1962 is still sold[21]. This small VOM has only four ranges for each of DC Volts, AC Volts, Milliamperes, and Ohms, but it has the same sensitivity of 20,000 Ohms/Volt D.C., and 5,000 Ohms/Volt A.C. as the Triplett 630 VOM. It is clever and compact, but its fate is sealed...I just recently, out of curiosity, picked up a thin calling-card sized auto-ranging VOM with a liquid crystal digital display and it cost $7.00 with test prods, mercury battery, and pocket case.

There is an old adage (the 2nd Law of Thermodynamics?) which applies to this sad inevitability, "Everything degrades with time", which gives good reason to reach back and celebrate the quality of the surviving vintage instruments, which were made while analog moving coil meters were at their innovative best, and when Triplett in particular, achieved excellence in their handsome Model 630 series of meters. After many years of experience with so many remarkable instruments, I no longer *need* a meter, nor do I have my youthful "meter envy". Instead, my admiration for these carefully conceived and delicately made electromagnetic instruments just seems to grow.

Did you say *ONE MICROAMPERE* full scale?

REFERENCES

1 Weston 697 VOM; 1,000 Ohms/Volt AC/DC, Service, Jan, 1938, Advertisement, page 3.

2 The Weston 697 VOM: A 1930s Cutting-Edge Design by Charles C. Kirsten; AWA Journal, Jan & May, 2006.

3 Simpson 260 VOM; 20,000 Ohms/Volt DC, 1,000 Ohms/Volt AC, Operators Manual for Model 260, Form 71548, Simpson Electric Company, 1948, page 2.

4 Triplett Deluxe Set Tester Model 1601; (25,000 Ohms/Volt D.C.) Radio News, Nov, 1937, Advertisement inside front cover.

5 Triplett Volt-Ohm-Milliammeter Model 1200-E (25,000 Ohms/Volt D.C.), Radio News, Jan, 1938, Advertisement page 422.

6 Important Points in Designing a Set Tester, by Samual C. Milbourne, Radio News, Jan. 1938, page 404, and Feb, 1938, page 461. Covers the Supreme Set Tester Model 541; "The new Supreme-Westinghouse Meter is used in this model with a choice of either a 1 Ma.(1,000 Ohms per volt) or a 40 microampere (25,000 ohms-per-volt) movement."

7 Supreme Instruments Set Tester Model 592, (25,000 Ohms/Volt D.C.) Radio News, Oct. 1938, page 45.

8 Hickok Electrical Instruments Model 4900 S Zero Current Voltmeter (Infinite Ohms/Volt D.C.) Radio News, Nov, 1938, page 52.
9 Weston Super-Sensitive Analyzer Model 772; (20,000 Ohms/Volt D.C.) Radio News, Feb, 1938, Advertisement page 493.
10 Mountings of Triplett Pivots; (Advertisement), RADIO, March, 1936, page 80.
11 Triplett Volt Ohm Milliammeter Model 630; (20,000 Ohms/Volt D.C.) Radio News, July, 1938, Premier advertisement, pg 16, 17.
12 Triplett Volt Ohm Milliammeter Model 630-A; High accuracy version of the Model 630, with the same 20,000 Ohm/V D.C. and 5,000 Ohm/Volt A.C. sensitivity as the 630, but equipped with all ½% precision resistors, and a Red Dot mirrored scale meter. Radio & TV News, June, 1957, Introductory Advertisement, 3rd Cover.
13 Triplett Volt Ohmmeter products including the 630 VOM Models 630, 630-A, 630-APL, 630-NA, 630-PL, 630-T, and 631, are shown with short descriptive paragraphs for each model; Electronics World, Nov, 1959, Advertisement, 3rd Cover.
14 Triplett Volt Ohm Milliammeter/ Vacuum Tube Voltmeter, Model 631; Introducing the double purpose VOM/ VTVM. Sensitivity: VOM; 20,000 Ohms/Volt D.C., and 5,000 Ohms/Volt A.C.. VTVM; Input resistance 11 Megohms on all ranges from 1.2V to 120V. Radio & Television News, July, 1956, Introductory adv., 3rd Cover.
15 RCA Receiving Tube Manual, Technical Series RC-16; page 81, 1R5 Data; "NOTE: The transconductance between grid No. 1, and grids No 2 and No. 4 tied to plate (not oscillating), is approximately 1400 micromhos under the following conditions: grids No. 1 and No. 3 at 0 Volts; grids No. 2 and No. 4, and plate at 67.5 volts."
16 Vacuum Tube Voltmeters, by John F. Rider; John F. Rider Publishers, Inc, New York, N.Y. 1941, page 121
17 Catalog 70, Sensitive Research Corporation, 310-316 Main St. New Rochelle, New York, 1956, pages 79, and 203.
18 Triplett Volt Ohm Milliammeter Model 630-NA; Triplett's first use of the "VA/2" switch on a 630 VOM which halved the meter sensitivity from 20,000 Ohms/Volt to 10,000 Ohms/Volt, and doubled the number of voltage ranges to 70. This was the first 630 VOM to use an auxiliary function switch concentric with the "one control" master range switch; Radio & Television News, May, 1955, Adv. 3rd Cover.
19 Triplett Volt Ohm Milliammeter Model 625-NA, The first Triplett VOM to use a "VA/2" shunt switch which halved the meter sensitivity from 20,000 Ohms/Volt to 10,000 Ohms/Volt. This doubled the voltmeter ranges, and halved the sensitivity. The meter was marketed as having 12 D.C. Voltage ranges; Radio News, April. 1948, Adv. page 29.
20 Triplett 2000-2001 Short Form Catalog; Model 630 Series, Model 630-NS, 200k/100k Ohms/Volt, 1.5% of full scale accy.
21 Triplett Volt Ohm Milliammeter Model 310; Pocket size VOM with the same sensitivity (20,000 Ohm/Volt D.C., and 5,000 Ohm/Volt A.C.) and much the same capability of the larger 630 VOM; Electronics World, Jan, 1962, Introductory adv., 3rd Cover.

This article was peer-reviewed.

Photo credits: Charles Kirsten

Triplett 630 VOM

ABOUT THE AUTHOR

Charles C. Kirsten is a retiree from over 50 years of electronic and communications engineering. His interest in radio began at age nine, when he was given a crystal set to occupy him during an episode of childhood illness. This led to a love of music, home radio construction, and later radio repair as an avocation with a toolmaker's apprenticeship at Pratt & Whitney Aircraft.

Enlistment in the US Navy during WWII brought training in RADAR, SONAR, and communications, and service on Guam as an ETM/2C. Post war studies at UCLA while working at Beckman Instruments Research resulted in a BSEE, and a career shift to the Telecommunications Division of Caltech's Jet Propulsion Laboratories (JPL).

The transfer of JPL from the Army to NASA came during the exciting days of these transitions: vacuum tube to solid state, analog to digital, L/C tuning to phase-locked loop signal acquisition, carrier signal to pseudo-noise coded spread spectrum reception, main-frame to personal computer, battery power to solar cells, and domestically, from radio to color television and talking cars. Charles found his job as an electronic engineer designing telemetry and command systems for unmanned interplanetary spacecraft demanding, but still found time to earn an MSEE at UCLA. Engineers ran fast just to stand still.

Charles' interest in collecting old radios began in 1976 while he was assigned to NASA Headquarters in Washington, D. C. After each of several trips to Geneva, Switzerland as a member of the Committee Consultatif Internationale Radiotelephonique, Charles took time to stop in Paris and peruse the stalls at the Marche aux Puces and Les Halles Antique Center, looking for antique Recepteurs de Telephonie Sans Fils.

Recently, Charles has been spending his time analyzing vintage test equipment and writing articles on the unusual and innovative approaches to be found there. He has written a few short articles for *ARC*, and the *AWA Journal*. This is his second article to appear in the *AWA Review*.

Life Memberships: Antique Wireless Association, Tau Beta Pi (Engineering Honorary, UCLA), Sigma Xi, (Science Honorary, Caltech). Past Memberships: Institute of Radio Engineers, Inst. of Electrical and Electronic Engineers, Consultative Committee on International Radio.

AWA Review

Radio Pioneer Dr. David G. McCaa

Lloyd Jury and Brian Belanger

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ABSTRACT

Few radio historians would recognize the name David Galen McCaa. Yet Pennsylvania newspapers described McCaa as "the inventor of the wireless telephone," and "the foremost inventor of his time in everything concerning wireless telephony of which he undoubtedly, was the originator." Research in local historical records, and interviews with family members, has made it possible to reconstruct McCaa's life and his contributions to radio technology. This article emphasizes his radio work during the period between 1910 and 1930. Had World War I not broken out, McCaa might have become a manufacturer of wireless telephony equipment. During the war he worked briefly for the National Bureau of Standards and also had ties to the California-based Federal Telegraph Company.

INTRODUCTION

When asked to name "radio pioneers," most Americans would be hard pressed to come up with names beyond Marconi and de Forest, if they could recall even those two. Very few people outside the antique radio fraternity are familiar with the work of "lesser-known to the public" radio pioneers, such as Reginald Fessenden and Charles Herrold. And then there are radio pioneers who are unknown even to those who have studied radio history diligently, simply because no one has yet documented their accomplishments. David Galen McCaa (pronounced "McCay") is just such an individual. Local newspapers circa 1914 described McCaa as "the inventor of the wireless telephone,"[1] and a decade later local papers described him as "the foremost inventor of his time in everything concerning wireless telephony of which he undoubtedly, was the originator."[2] McCaa certainly was not the first to transmit the human voice by radio, but he definitely deserves to be called a pioneer in radiotelephony, and his radio work documented.

Author Jury who lives in the Lancaster, Pa. area where McCaa did his radio work, has spent years researching McCaa. He contacted family members and friends who knew McCaa, pored over old newspapers, and gathered a wealth of material, some of which was displayed at a recent AWA annual convention.

Most of the material from which this article was taken came from newspaper clippings. Some of the clippings were missing key source data, such as the name of the newspaper or the date of the article. Nevertheless, the available information enables a fairly thorough documentation of

McCaa's radio work.

A BRIEF BIOGRAPHY OF D. G. McCAA[3]

David Galen McCaa (Fig. 1), the son of Dr. David J. and Eugenie Bickham McCaa, was born in 1882 in Ephrata, Pa. He graduated from Ephrata High School in 1898, and studied at the Medico-Chirurgical College in Philadelphia (which later became part of the University of Pennsylvania Medical School). In 1903 he had the highest average in his class. He began his medical career as a radiologist at the General Hospital in Lancaster, Pa. The radio work described in this article was carried out primarily in the period between 1910 and 1930.

During World War I he worked briefly for the National Bureau of Standards in Washington, D.C., in radio-related work. In the 1930s he worked for Philco on projects such as AVC circuits. During the 1940s, until his retirement, he worked for the Army Signal Corps at Fort Monmouth, N.J. in the group concerned with piezo-electric (crystal) frequency control techniques and crystal grinding. He died June 22, 1954 in Long Branch, N.J. at the age of 72. His wife M. Estella Yeiser died a few years before him. He had a son, Robert, and two grandchildren.

FIRST RADIOPHONE BROADCASTS

McCaa's research began early in the 20th century with attempts to improve X-ray machines. He was granted a patent for improved X-ray technology, the rights to which he sold to a physicians' supply house, E. B. Meyrowitz of New York. (A complete list of McCaa's patents is provided in Table 1.) This success probably whetted his appetite for inventing.

Fig 1. David Galen McCaa, circa 1925.

Sometime around 1907, McCaa became interested in radiotelephony (perhaps he had read of Fessenden's successs at Brant Rock) and he turned his attention in his spare time to radio experimentation. By 1913 he had become an active ham with state-of-the-art equipment, and he was transmitting voice signals.[4] His first public broadcast, with an arc transmitter (date uncertain), was said to have been from a transmitter installed at the local YMCA to a receiver at the Union Stock Yards. Beginning in October 1913 he lectured on wireless at the YMCA, and formed a local radio club. A Lancaster ham friend, Christopher Bowman, worked with McCaa in some of his earliest tests of voice transmission.[5] His experiments gen-

erated tremendous interest on the part of the local newspapers, which did not appear to be familiar with earlier radiotelephone broadcasts such as those of Herrold or deForest.

Seeking more recognition for his work, McCaa established a large new transmitting station at Mountville, Pa.[6] Figs. 2 through 4 show McCaa's station. F. M. Sammis of the Marconi Wireless Telegraph Company visited the site and pronounced it "the last word in wireless." Robert H. Marriott, radio inspector for the New York District of the U.S. Department of Commerce and Labor also inspected the station and stated that "he was satisfactorily convinced of the efficiency and practicability of the new invention." Newspaper articles of the day noted that his transmissions from Mountville "could be heard with the utmost ease by everybody..."[7] at the receiving station in York, Pa., where his assistant, W. Goldie Wade operated the receiver, and that McCaa "had solved the secret of wireless telephony."[8] Reporters said "it is understood that there are interests backed by millions of dollars who have been eagerly awaiting the outcome of the experiments of this gifted young man."

RADIOTELEPHONE GOES TO SEA

In 1914 McCaa installed a radiotelephone transmitter on the *S.S. Tyler* of the Old Dominion Steamship Line, to demonstrate his system for the U.S. government. Robert Marriott, the government radio inspector noted above, witnessed the tests

Fig 2. Transmitter building at McCaa's Mountville, Pa. site, circa 1913.

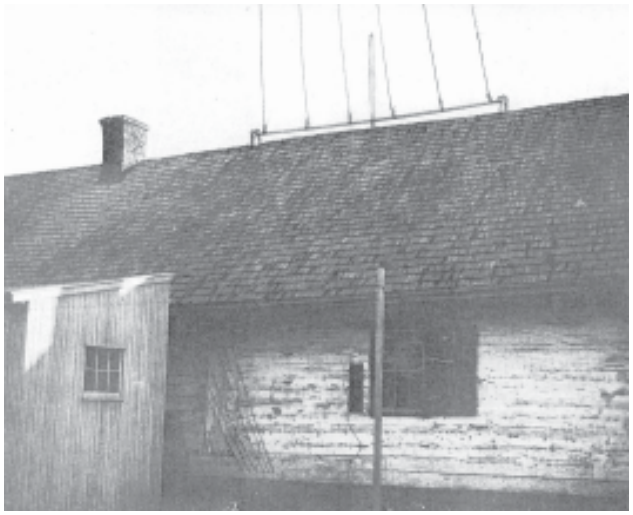


Fig 3. Rear view of the Mountsville transmitter building

and provided instrumentation to evaluate the signal strength. Marriott must have been eager to have the tests done. An unidentified newspaper clipping says that Marriott was a personal friend of the president of the Old Dominion Steamship Line, and that it was Marriott who arranged for McCaa to get access to the *Tyler* for the tests.

McCaa and his assistant W. G. Wade made experimental voice and music transmissions on the 600-meter wavelength, including cornet solos by one of the ship's crew, as the ship sailed from New York to Norfolk.[9] The *New York Herald* made its wireless telegraph station WHB at the Battery available for the tests, along with a senior operator, Arthur Coleman. The receiver at the Battery consisted of a loose coupler and a crystal detector. McCaa's transmitter

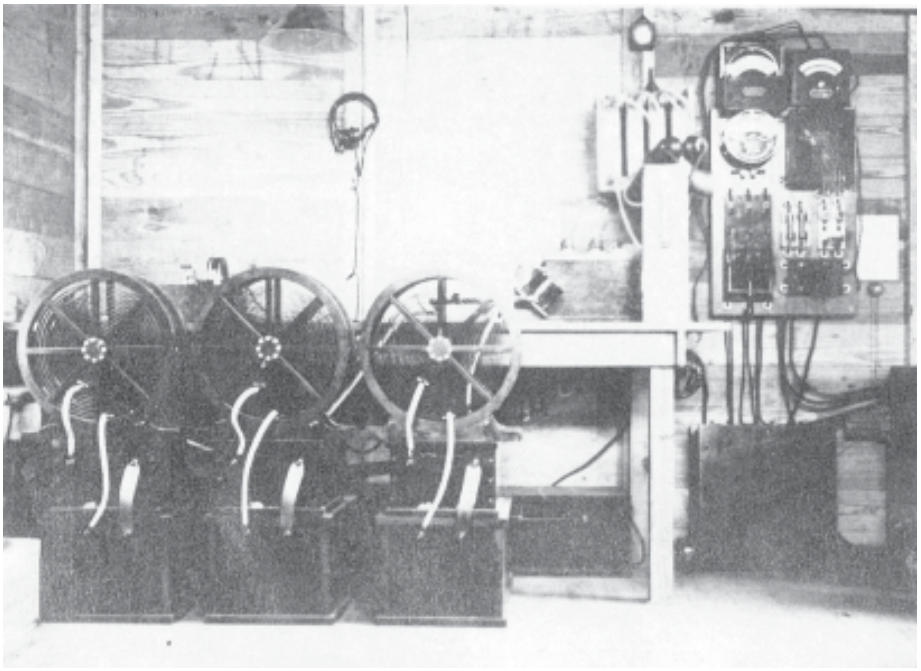


Fig 4. Power supply apparatus for McCaa's Mountville transmitter.

used a three-phase AC supply to drive three primary circuits, each with its own spark gap. This provided a sufficiently continuous RF signal that it could be modulated with the audio signal. In spite of the enthusiasm of the listeners, the audio quality was likely rather poor.

The *Herald* reported that the voice signals from the *Tyler* were "heard without the least difficulty, and entirely free from any grating or buzzing that frequently is heard on wire telephones." Satisfactory reception was maintained during much of the *Tyler's* voyage south. Marriott commented "This will mean much to navigation. Particularly will it be valuable to vessels in distress...It will also mean that a much greater volume of words may be carried than by wireless telegraphs. From the investigations I have made, this is the most perfect wireless telephone so far invented." The next day, Marriott told the *Herald* that with more powerful transmitters of the type developed by McCaa "Easy wireless telephone communication with Europe is in sight in the near future."[10] He added, "While Dr. McCaa's invention is incomplete, I am sure that he will develop it until the voice can be sent through the air as far as wireless telegrams are at the present time."

The *Herald* said that shipping company officials besieged the *Herald's* wireless station with inquiries about McCaa's new development because it meant that ships might no longer have to employ skilled radio operators proficient in code transmission. The newspaper added, "...the captain of a ship in distress may call for help through the telephone, the same as he would call to his engineer through the engine room speaking tube." One front-page article in the *Herald* headlined McCaa's success as "New Wireless Telephone Sensation," and, "Opens New Era in Radio Science."[11] Enthusiasm was widespread. A shipping company official said, "It seems like an Aladdin's dream when we say it is now possible to hold personal conversation over a distance of a hundred miles or more and use the ether as a carrier for the human voice."

Experimental transmissions continued on the return trip back to New York.[12] The operator at the Norfolk Navy Yard described the signals as "very distinct." Amateur radio operators in the Norfolk area also reported picking up McCaa's transmissions. Even the Telefunken station at Saybrook, Long Island, reported hearing the *Tyler*.[13]

The Norfolk newspaper reported, "Asked if there was any relative or similarity between his telephone and the Marconiphone, which has recently been undergoing a series of tests in Europe, the inventor said that he had never seen or studied a Marconiphone and that if there should be similarity, it would be a mere coincidence." A 1925 newspaper article noted that McCaa's transmitter used for the tests on the *Tyler* was later found to violate patents owned by the Marconi Company, so it had to be redesigned.[14] McCaa later wrote that by 1917 he had come up with a

design that did not infringe Marconi's patents.[15]

Of course other radio developers in the United States as well as in other nations such as England, Germany, and Italy were also experimenting with wireless telephones during the same time period. The *Herald* noted that wireless telephone equipment from another company had been installed on the United Fruit Company ship, the *Almirante* five weeks earlier. Charles Herrold in California had been making radio telephone broadcasts with considerable success before McCaa, as had Lee deForest in New York City. No doubt some of the hype about McCaa in the local papers can be attributed to a combination of home town boosterism plus a lack of detailed knowledge of what other radio pioneers had already accomplished. The *Lancaster Intelligencer* addressed the issue of competing wireless telephony systems as follows[16]:

"...because it is well known that there have been quite a number of claimants to the invention of a wireless telephone in the latest encyclopedias, one may read the record of the claims and supposed achievements of those inventors, without, however, learning much of the utterly futile and unsatisfactory character of everything that has really been done up to this epoch-making achievement of Dr. D. G. McCaa of Lancaster. To state the matter briefly, Dr. D. G. McCaa has produced an entirely new and original system of telephoning without wires, the distinguishing merits of which are economy of installation, absolute freedom from disturbance from high potential currents, and regularity and certainty of operation. The apparatus, in short, is not a delicate scientific instrument, suitable only for interesting scientific demonstration, but a practical working machine for the common service of man in everyday use."

The same article went on to claim that the U.S. Navy's tests of wireless telephony in the Atlantic fleet some years earlier were largely unsuccessful. While it had been shown possible to telephone from ship to ship over short distances, "the conditions had to be just right, the apparatus was easily thrown into hopeless disorder and the entire costly equipment might be 'burnt out' and ruined by uncontrollable currents. Protection from these currents, or the development of a system which would not be affected by them has been the aim of inventors and experimenters in the fields of wireless telegraphy and telephony, who number a score; the most prominent systems being the Marconi, the deForest, the Fessenden, the Poulsen, the Majorana and the Telefunken."

Certainly other inventors such as deForest would have argued vociferously that McCaa's system was not unique in spite of the enthusiasm for it displayed by the newspapers in Eastern Pennsylvania.

THE McCAA RADIO COMPANY

McCaa apparently was careful to protect his intellectual property. When he left his laboratory at night, he would take

key pieces of apparatus home with him lest some industrial spy break into his laboratory in order to reverse engineer his apparatus. Of course once a patent was issued, then anyone could read it and see what he had done.

McCaa became quite a celebrity in Lancaster, Shortly after his trip on the *Tyler* the *Pathe Weekly* newsreel featured him. The movie theater in Lancaster proudly urged residents to come to the theater to see a local boy in the news. He received numerous invitations for after dinner speaking engagements and lectures, many of which he accepted, and which were covered by East Coast newspapers. Examples include talks to the Northampton Club, Franklin and Marshall College, the York Engineering Society, and the Young Business Man's Club of Philadelphia.[17]

In October 1914 at age 33 he formed the McCaa Radio Company with the help of Henry S. Williamson and a lawyer, M. E. Musser, who became treasurer.[18] Williamson was described as McCaa's "chief backer"[19] and someone who "has been generously financing Dr. McCaa's invention." Following McCaa's successful demonstration on the *Tyler*, Williamson had hosted a banquet at the Hamilton club to honor him. A local paper said Williamson "has taken a keen interest in the work of the young inventor and has greatly aided in winning him the success that is now in sight." The company was capitalized at $14,000, with the initial stock price set at $100 per share.

In November 1914 ground was broken for the company's new 20- by 40-foot two-story laboratory on School Lane, south of Marietta Pike, across the street from H. S. Williamson's elegant home, "Upland Lawn." The new building was described as "the first permanent land station devoted entirely to radio telephony."[20] The site was chosen because it was the highest ground in the area, and the company intended to erect 150-foot-high steel towers 260 feet apart to support an antenna. The basement held motors and generators; the first floor, the operating room (See Figs. 5-8). By the summer of 1915, McCaa was giving demonstrations for journalists at his new facility and said he was ready to begin manufacturing and selling wireless telephone gear.[21]

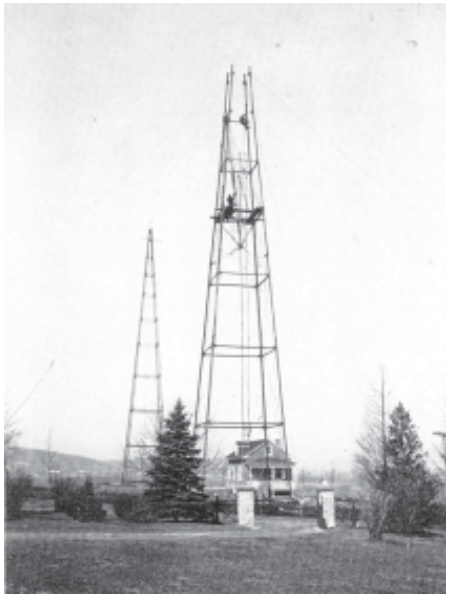


Fig 5. Construction of the antenna towers at McCaa'a North School Lane transmitter site, Winter of 1914-15.

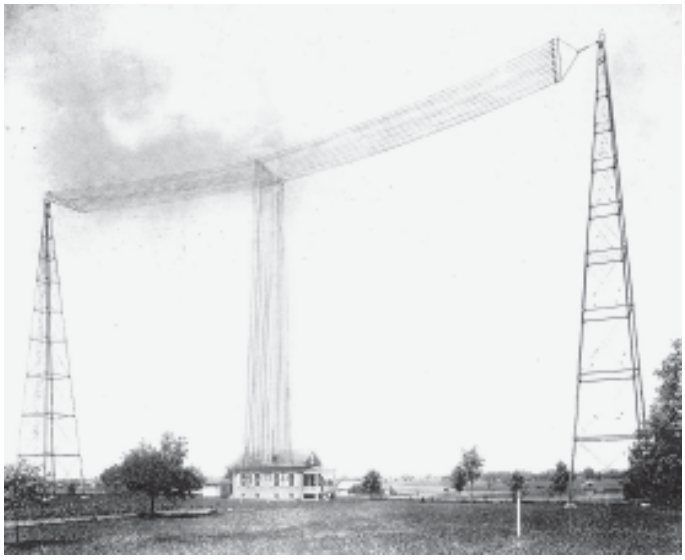


Fig 6. Completed antenna system at the N. School Lane site, looking North, 1915.

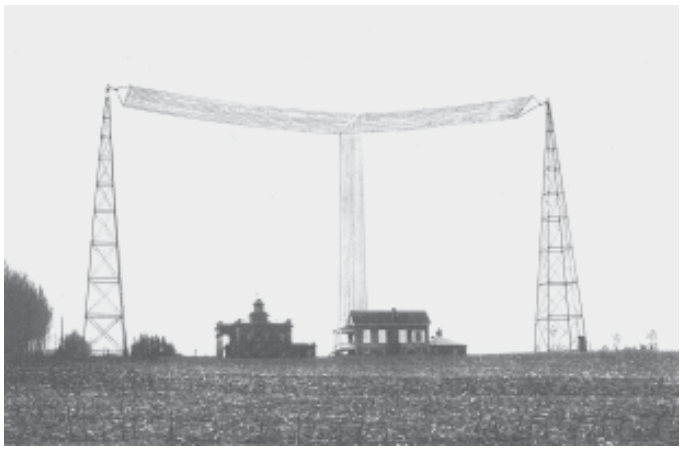


Fig 7. Antenna system at the N. School Lane site, looking South, 1915.

Late in 1914 McCaa was constructing a station atop the municipal ferry terminal at the Battery in New York City with which to continue tests involving his apparatus installed on Old Dominion Line ships. In January 1915 the *Herald* reported on continuing tests between its Battery station and the *Tyler*.[22] By then high quality communication up to 150 miles had been achieved. Messages from ships at sea were being relayed by a landline telephone link to the *Herald's* main offices in Herald Square in New York City. Some accounts described the transmissions as "perfect" and "clear" but others talked about "straining ears..." suggesting that the transmissions were far from "perfect."

Within days, a Panama Railroad Line ship 350 miles from the *Tyler* reported hearing its radiotelephone signals, thereby setting a new distance record for McCaa.[23, 24] Numerous other stations up and down the East Coast, such as the Brooklyn Navy Yard station, and even the YMCA Wireless Club in Lancaster reported that they were hearing the *Tyler* loud and clear. By July 1915 reception up to 485 miles had been reported.[25]

In December 1916 McCaa learned that the U.S. Patent Office had allowed all six of the wireless telephony patent

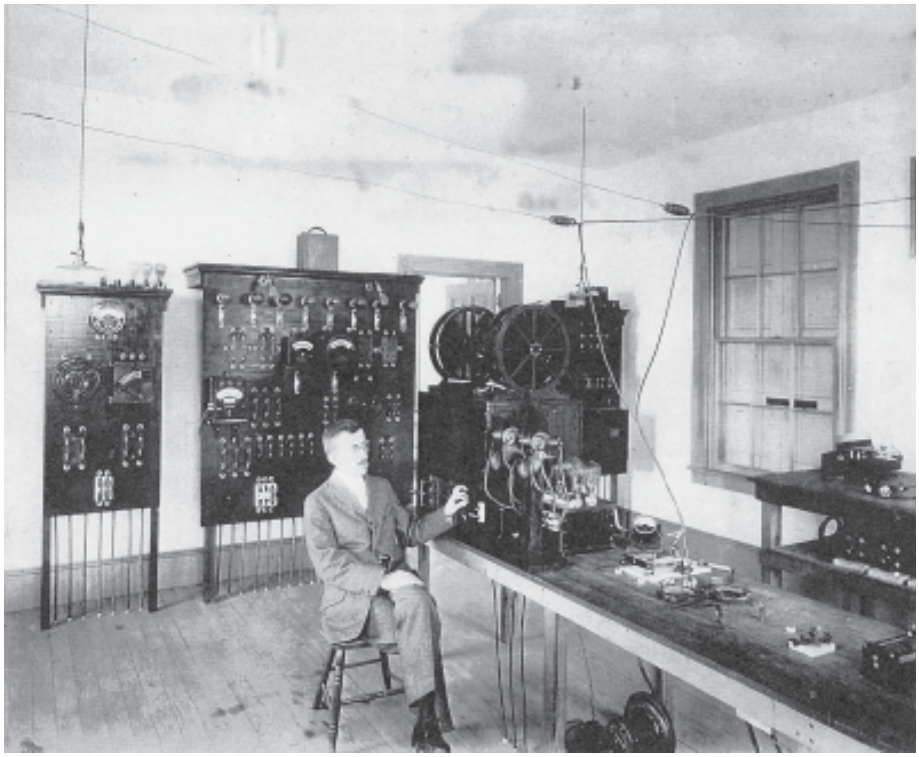


Fig 8. Main operating room of N. School Lane radiotelephone station, circa 1915.

claims he had filed.[26] In March 1916, Dr. J. Zenneck, a prominent wireless authority from Munich, Germany, visited the McCaa Radio Company. He witnessed and was impressed by demonstrations of McCaa's technology.

By July 1916 McCaa was testing new improved apparatus on the *Tyler*. A newspaper article does not indicate the nature of the technology, but said "The new system is said to be able to do with one-half a kilowatt, the same amount of work for which other systems require one or two kilowatts. Besides, it dispenses altogether with condensers."[27] In 1918 the *Tyler* was in a convoy on its way from the U.S. to an Italian port when it was torpedoed and sunk in the Mediterranian, thereby ending its career as a radio test vehicle for McCaa.

An August 1916 report said that when McCaa began to manufacture equipment, well-known wireless entrepreneur Col. John Firth was to be the sales agent.[28] That article also added that the new improved McCaa system lowered costs because "Two of the most expensive parts used in the usual sets are entirely done away with, namely, the high voltage condensers and the variable coupling transformer."

Shortly before the United States entered World War I, the McCaa Radio Company acquired another building in the Lancaster area--the National Biscuit Company building on

North Arch Street. The front of the building was converted to office space while the rest of the building was intended to be a manufacturing facility. Experiments continued at the laboratory building on School Road. No doubt Dr. McCaa hoped to become a major manufacturer of radio apparatus. Unfortunately the War doomed those plans.

WORLD WAR I SHUTS DOWN McCAA's EXPERIMENTS

When the United States entered World War I, the Navy took over control of radio stations and required that amateurs disassemble their transmitting apparatus and take down their antennas. Needless to say, this caused great hardship for the McCaa Radio Company. With no opportunity to be on the air and to carry out tests, radio development apparently ground to a halt. If only McCaa had had a functioning factory at the onset of the War, he might have received government contracts to build radio equipment, but the record suggests that his factory had not geared up for large scale manufacturing. No doubt this created a financial hardship for him as well as being devastating for someone who thrived on radio research.

One unidentified newspaper clipping stated that the McCaa Radio Company had received 105 orders for shipboard radio sets and that production had just begun when the company shut down at the outbreak of the war.

It was during this period that McCaa went to Washington, D.C., to work in the radio laboratory at the Bureau of Standards. The Bureau's history books do not mention McCaa, which would suggest that he was not there very long and that he did not produce any major accomplishments during his stay. A 1947 letter from McCaa to the personnel people at Ft. Monmouth seeking a promotion provides more data on his activities around the time of World War I:

"The entry of the United States into the 1st World War prevented further commercial development of the systems that had been patented, and the applicant entered the Bureau of Standards as assistant physicist. While there, the applicant developed a special tone modulated radio transmitter and receiver system and assisted in the field work carried out in the development of the radio compass. While at the Bureau of Standards, applicant became interested in the radio interference problem and carried out preliminary tests at his residence. The data were presented to the Bureau but a satisfactory arrangement could not be made to carry on the development work at the Bureau."

The large towers at the laboratory site were sold to another firm that disassembled them to reuse the structural steel. By June 1920, one had come down and the other was slated to be disassembled.

THE EARLY 1920s

By 1920, McCaa must have returned to Lancaster and taken up radio again, because in May 1920 a representative of the

Pennsylvania State Police was meeting with McCaa to discuss equipping the police barracks across the state with radio links.[29]

If McCaa was considering going back into manufacturing, he, like many other small companies, was undoubtedly stymied by the patent situation whereby large corporations like RCA, AT&T, and Westinghouse held key patents that others would need access to in order to be able to offer state-of-the-art radio systems. While McCaa praised the bright future of radio telephony in an inteview, the *Daily Intelligencer* quoted him as saying, "At the same time, Dr. McCaa charged that the whole radio-phone situation was seriously hampered by the patent gag which has been placed upon it, and declared that patent rights held on various articles by big concerns are tending to discourage invention and development of the business." A small firm like the McCaa Radio Company would be hard pressed to get patent licenses from "the biggies" at affordable prices. McCaa continued, "It is almost impossible to go ahead with radio-phone work without facing trouble by infringement of patents and in some cases, patent rights held on some minor piece of mechanism which is necessary for experiment will bring important work to an abrupt end."[30]

The interview quoted in the paragraph above strongly suggested that McCaa was about to give up his hopes of being a radio manufacturer because of the patent situation.

WORK ON STATIC REDUCTION

Static plagued early AM radio broadcasts and many researchers strived to find ways to reduce or eliminate it. After he left the Bureau of Standards, McCaa devoted his full attention to static reduction. By 1919 he claimed to have made substantial progress in that regard and applied for a patent. An October 8, 1920 newspaper article[31] says that McCaa sold the U.S. rights to his anti-static invention to Federal (the California-based communications firm) for a considerable amount, and would be going to California to help the company apply the new "device [which is] attached to an ordinary receiving circuit."

A newspaper clipping from an unidentified Lancaster area paper datelined October 20, 1920, says that McCaa and his wife were preparing to leave for Palo Alto, Calif., where he planned to spend at least a year working for Federal.

Another unidentified clipping, apparently from a few years later, says: "The Electric Apparatus Company, of Parkesburg, a large corporation, organized for the purpose of scientific research along radio lines, and Dr. D. Galen McCaa, who is associated with it, are receiving inquiries from English interests concerning the patent rights for the anti-static system invented by Dr. McCaa several years ago. The patents were all granted about five weeks ago and are due to be issued within a few days. Negotiations are now under way with the English interests, and the matter of selling

the foreign rights outright or licensing them for royalties is under consideration. The invention promises much in the radio world for the elimination of static in radio intercourse, according to the patentee."

Still another unidentified clipping describing McCaa's return to the Lancaster area says he "has returned to his home here after two years spent in radio research work on the Pacific Coast...," which suggests that his return to Pennsylvania was sometime in the fall of 1922. It mentions "his laboratory in Ephrata," which other clippings indicate was actually a small building at the rear of his home. Later clippings (1923) mention that McCaa was working in the Parkesburg laboratories of Horace A. Beale, Jr., and that Beale was "the multi-millionaire" president of the Parkesburg Iron Works, and operator of broadcast station WQAA.[32] (In 1926, WQAA was a 500-watt station on 1360 kHz.[33]) Beale also served on the Board of Directors of the ARRL and operated well-known amateur station 3ZO.

The four-day Electrical Show held at the Arcade Garage in Lancaster beginning on October 18, 1922 was apparently a major event, with Thomas Edison opening the show with remarks delivered via radiophone from his laboratory in New Jersey and played over a PA system in the hall.[34] The newspaper said "There will be everything that is the last word in electrical appliances and the show will equal any endeavor made in cities of the very first rank." Demonstrations of McCaa's radio technology were a "main feature" of the event. Roughly 20,000 people attended.

In January 1923 McCaa, Beale (who was also president of the Chester County Radio Association), Thomas Appleby, Wynn Colman, and N. G. Richardson left Pennsylvania by train in Beale's private railroad car "Commonwealth" to spend two weeks in the Gulf Coast region near Sarasota, Fl., experimenting with McCaa's static elimination system.[35] (Appleby was a radio expert who later wrote a book about Mahlon Loomis's early wireless experiments.)

The rationale for the trip was that McCaa wanted to continue his experiments with static elimination, and there were thunderstorms in the Sarasota area in January, but none in Pennsylvania. The tests were said to have been a complete success, and that McCaa hoped to begin manufacturing his system soon.[36] Comparing the multiple clippings about this event reveals how newspaper reporters get things wrong. Some call Beale's home town "Parksburg," some "Parkersburg," and one even mistook Parkesburg, Pa. for Parkersburg, W.V. McCaa and colleagues returned to Sarasota in March for more tests.

McCAA's APPROACH TO STATIC REDUCTION

An undated clipping from this time period sheds more light on the nature of McCaa's anti-static system. It says:

"It [the anti-static de-

vice] is composed of an oscillator and inductance of special design, the whole connected in such manner that it can be added as an auxiliary tuner before any type of radio receiving set.

"His experiments were based on the theory that static and power leaks from electric wires, carrying heavy loads, affect receiving antennae, regardless of the wavelength tuned. The result is a 'shock' which affects the detector, tube, or crystal, as the case may be.

"Tuning the radio receiver to the station which is desired, with the additional operation of tuning the static to a wavelength NOT desired, would eliminate that interference with resultant clarity of desired signals."

Those descriptions were not terribly revealing, but fortunately more detailed articles appeared in the technical literature to explain how McCaa's antistatic schemes worked. The idea was not to reduce the static to zero, but rather to reduce it to the same level as that of the desired signal, greatly aiding intelligibility. The literature describes multiple circuit variants, some of which were intended for radio telegraphy and others for radiotelephony.[37-40] Careful explanation of these many variants and reproducing all their schematics is probably more detail than is justified for this type of article. Libraries such as those of the AWA and the Radio & Television Museum can supply photocopies of the articles referenced for anyone who wishes to delve in depth into McCaa's circuitry. Instead, a very brief explanation of the concept plus an example are presented.

Begin with Fig. 9. The primary of the antenna transformer (the inductance between the antenna and ground) is split into two balanced coils, P1 and P2. A large inductance coil (L) is in parallel with a switch and coil P2. For radio telegraphy applications, an oscillator, here called a driver, is coupled to coil L.

At the radio frequencies of interest, coil L's inductance is sufficiently high that with the switch open and the oscillator off, nearly all of RF signals from the antenna flow through P1 and P2 in series. In that situation, the coils can be adjusted so that P1 and P2 balance each other out, and little or no signal (along with its accompanying static) reaches the secondary. When the oscillator is turned on and the coils are adjusted properly, the signal that is re-injected into the secondary contains both the desired signal and the static, but with the peaks in a 1 to 1 ratio, instead of with the static peaks much higher than the amplitude of the desired signal. The result is a dramatic improvement in signal to noise ratio.

In the case of radiotelephony, the oscillator is replaced by a non-oscillating vacuum tube "repeater" as indicated in Fig. 10. Here the coil L is split into two sections in parallel with the antenna coil closest to ground (P2), and a vacuum tube amplifier circuit is coupled to these coils. If adjusted incorrectly, the circuit will oscillate. With the vacuum tube turned off, and the switch closed, the

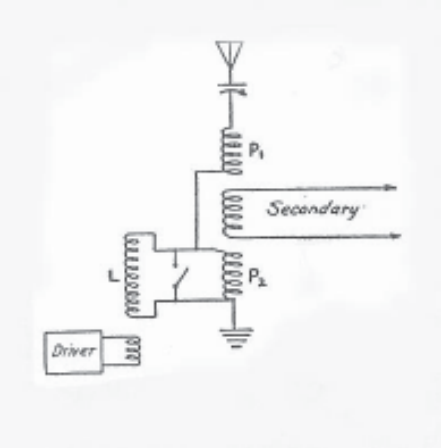


Fig 9. Conceptual description of the McCaa static reduction system. For radiotelegraph operation, the "driver" is an oscillator.

operator tunes the antenna circuit so as to receive the desired signal (plus whatever static accompanies it). Then the switch is opened and the coupling of the two coils is adjusted such that the signal; and accompanying static are balanced out (tune for minimum signal as before). Then the tube is lit, its grid and plate circuits adjusted, and as it warms up, it serves to restrict the amplitude of the static to no more than that of the desired signal. The resulting signal is fed back into the antenna circuit and into a normal receiver. A crystal detector, a Neutrodyne, or a superhet would work with the anti-static devices, but not a regenerative set, which would lead to instability.

Another key to success in McCaa's receiving setups was to completely shield the anti-static device and the receiver. Articles recommended using high-gain tubes for the repeater tube, such as the Western Electric 216-A or the RCA UV-201-A. Tubes such as the WD-11 or UV-199 were to be avoided. The *Radio Review* article cited above provided detailed instructions for how to couple the anti-static circuit to a conventional Neutrodyne receiver. The *QST* staff were very impressed with the performance of the device, it was said.

Another McCaa device described in these articles was his "band device," a type of mechanical audio notch filter useful for code reception (Fig. 11) Inserted between the detector and the audio amplifier, it used no tubes and had no controls to adjust. It involved a strip of soft iron, which in its mounted form resonated at about 1000 Hz. It

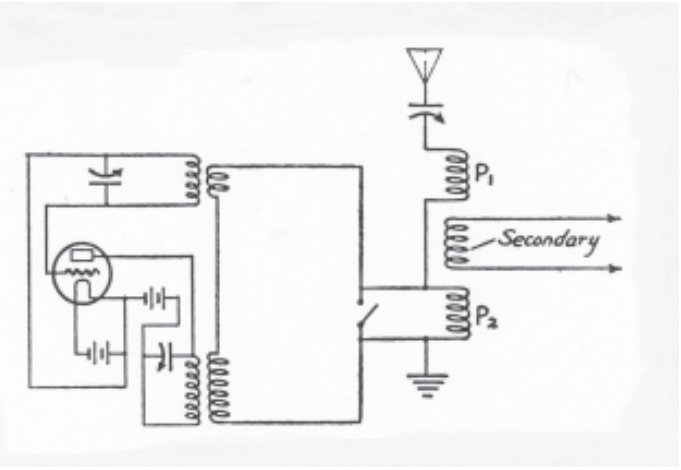


Fig 10. One version of the static reduction system. For radiotelephone operation operation, the vacuum tube is operated as an amplifier/modulator rather than an oscillator.

was driven by a Baldwin headphone with the diaphram removed, coupled to the iron bar on its input side. Another Baldwin phone was coupled to the output end and connected to the audio amplifier. Others had tried similar schemes, but McCaa's device supposedly was superior because it employed special transformers and tuned circuits that provided just the right amount of damping so that the iron bar would not continue to "ring" after the signal ceased.

OTHER RADIO ACTIVITIES

In 1924 McCaa wrote a series of radio tutorial articles for the *Lancaster New Era*. The paper described him as a radio "wizard."

Also in 1924, radio listeners and radio dealers in Lancaster became irate when a major source of radio interference appeared. Mass meetings were held, and 1800 people signed a petition to the local electric company, which employed arc devices suspected of being the cause of the interference, demanding that the company find and solve the problem. McCaa offered to head an investigation at no cost and, working with the Edison Electric Company, he was able to pinpoint the source of the noise, which turned out to be arc generator units at the Engleside Plant.[41] By replacing these units with rectifiers (at a cost of $27,000) the noise problem was solved, and McCaa became even more of a hero to local radio fans.

WORK FOR THE U.S. ARMY

McCaa continued to work on anti-static devices. His last patent on that topic was granted in 1941.

He entered the Signal Corps Engineering Laboratories on June 1, 1942. After a short tour of duty in vehicular installation, he joined the Crystal Branch in September 1942. By 1943 he was conducting training courses on crystal grinding. The demand for high quality crystals for precise frequency control was high during the war years, so McCaa's skill was undoubtedly greatly valued by the Army. In November 1943 the crystal grinding school was moved to Baltimore and McCaa set up the new school there. In January 1944 McCaa was sent to

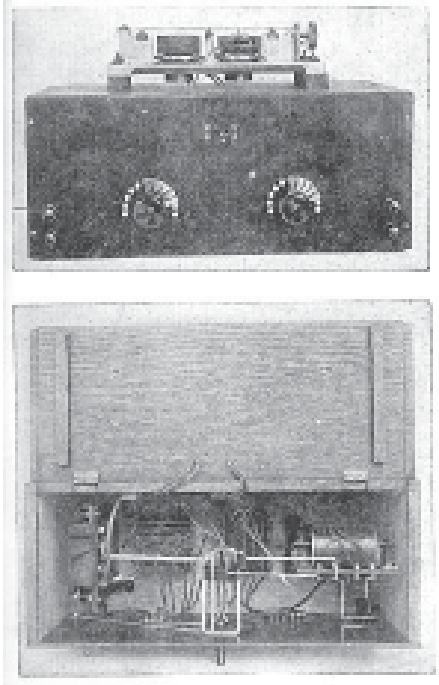


Fig 11. "Band selector," a mechanical notch filter.

Camp Coles to establish a crystal grinding school for civilian personnel, and he wrote a textbook on crystal processing.

In 1945 he was appointed Chief of the Research Section and later, Chief of the Frequency Components Section. He continued to work on piezo-electric devices and frequency topics during his career with the Army (Fig. 12). An article in the October 1949 *Radio & Television News* stated that McCaa and a colleague had developed new techniques to prevent deterioration of frequency control crystals.

So, to summarize, McCaa definitely qualifies as a radio pioneer. He is not the sole inventor of radio telephony as his hometown newspapers tended to claim, but his radio work certainly deserves to be documented.

ENDNOTES:

1 "Meeting of Radio Club," *Daily Intelligencer*, Lancaster, Pa., Nov. 18, 1913.
2 "Radio Startled Experimenters in Local Garret-Laboratory," *The New Era*, Lancaster, Pa., Jan. 22, 1923.
3 "Former City Physician, Radio Pioneer, Dies in New Jersey," *Daily Intelligencer*, Lancaster, Pa., June 24, 1954.
4 "Dr. M'Caa, Radio Expert, is Buried at Churchtown," *Ephrata Review*, Ephrata, Pa., July 1, 1954.
5 "Dr. M'Caa's Station Was on the Air Eight Years Before KDKA," *Lancaster New Era*, Lancaster, Pa., April 20, 1925.
6 "Lancaster Man is Working on a New Invention," *Daily Intelligencer*, Lancaster, Pa., Feb. 29, 1913.

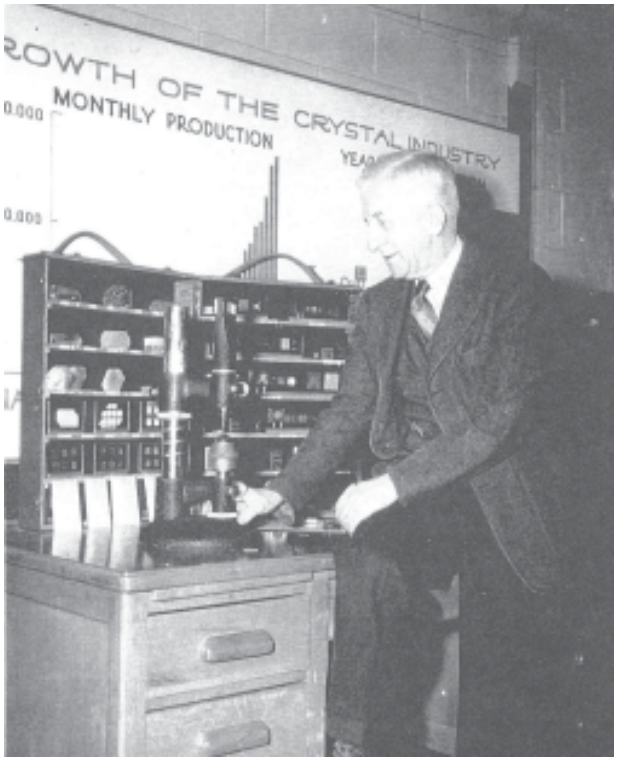


Fig 12. David G. McCaa in April 1945.

7 "Wireless Telephone Successfully Tested," *Daily Intelligencer*, Lancaster, Pa., Oct. 16, 1913.
8 "Physician Phones 16 Miles by His Wireless," *North American*, Philadelphia, Pa., Oct. 19, 1913.
9 "Telephone at Sea by Wireless to Herald Station," *New York Herald*, New York City, N.Y., June 10, 1914.
10 "O'er Sea Speech to Europe Now Near, Say Experts," *New York Herald*, New York City, N.Y., June 11, 1914.
11 "New Wireless Telephone Sensation When the Inventor at Sea Talks to Herald Office in Herald Square," *New York Herald*, New York City, N.Y., June 16, 1914.
12 "Wireless 'Phone Has Winning Test on Steamer Tyler," *Norfolk Pilot*, Norfolk, Va., June 11, 1914.
13 "Chat by Telephone 62 Miles at Sea," *New York Herald*, New York City, N.Y., June 15, 1914.
14 "Dr. M'Caa's Station Was on the Air Eight Years Before KDKA," *Lancaster New Era*, Lancaster, Pa., April 20, 1925
15 Letter from McCaa to Executive Secretary, Board of U.S. Civil Service Examiners, Ft. Monmouth, N.J., April 5, 1947 (photocopy in L. Jury collection).
16 "Success Followed Experiments of Three Years," *Daily Intelligencer*, Lancaster, Pa., June 13, 1914.
17 "Lighted his Pipe and Found Key of Wireless Wonder," *Evening Ledger*, Philadelphia, Pa., Nov. 27, 1914.
18 "The McCaa Company. A Charter Granted for the Manufacture of Radio Apparatus," *Daily Intelligencer*, Lancaster, Pa., Oct. 30, 1914.
19 "War News Direct by Lancaster Way," *Morning Journal*, Lancaster, Pa., Sept. 21, 1914.
20 "The McCaa Radio Company," *Daily Intelligencer*, Lancaster, Pa., Nov. 23, 1914.
21 "Wireless Telephone. Dr. D. G. McCaa Gives Demonstration to Newspaper Men and Some Friends," *The Reporter*, Ephrata, Pa., July 2, 1915.
22 "100 Miles at Sea, Captain Telephones to the Herald," *New York Herald*, New York City, N.Y., Jan. 9, 1915.
23 "M'Caa Wireless 'Phone Heard 350 Miles Away," *The New Era*, Lancaster, Pa., Jan. 13, 1915.
24 "M'Caa Wireless Stretches Out," *The Lancaster Morning Journal*, Lancaster, Pa., Jan. 14, 1915.
25 "Successful Tests of Wireless Telephone," *Lancaster Daily Examiner*, Lancaster, Pa., July 2, 1915.
26 "Dr. M'Caa Wins Patent Controversy," *Daily Intelligencer*, Lancaster, Pa., Dec. 17, 1915.
27 "New Wireless System Tested," *New York Herald*, New York City, N.Y., July 27, 1916.
28 "M'Caa Wirless Invention to be Manufactured in this City Soon," *Daily Intelligencer*, Lancaster, Pa., Aug. 7, 1916; "Organizing to Manufacture McCaa Wireless Equipment," *The New Era*, Lancaster, Pa., Aug. 7, 1916.
29 *Daily Intelligencer*, Lancaster, Pa., May 25, 1920.
30 "Wireless Phone to be Generally Used," *Daily Intelligencer*, Lancaster, Pa., Feb. 2, 1920.
31 "Wirless Invention is Sold by Dr. D. G. McCaa, of Ephrata", *News Journal*, Lancaster, Pa., October 8, 1920.
32 "Static Elimination Tests Successfully Completed," *Philadelphia Bulletin*, Philadelphia, Pa., Feb. 3, 1923.
33 Tom Kneitel, *Radio Station Treasury, 1900-1946*, (Commack, N.Y.: CRB Research, 1986), p. 34.
34 "Thomas Edison to Open Show," *Daily Intelligencer*, Lancaster, Pa., Oct. 18, 1922.
35 "Dr. M'Caa Will Work in South," *Daily Intelligencer*, Lancaster, Pa., Jan. 22, 1923.
36 "New Anti-Static Radio Receiver Proves Success," *Coatesville Record*, Coatsville, Pa., Feb. 9, 1923.

37 "Data on the McCaa Anti-Static Circuits," *Radio Review*, July 1925, p. 63
38 Edward B. Patterson, "Refinements in the McCaa Anti-Static Devices," *Radio*, March 1926, p. 11
39 "The McCaa Anti-Static Devices, Part I," *QST*, Feb. 1925, p. 8; "Part II," March 1925, p. 18
40 "Discussion of the McCaa Anti-Static Systems," *Philadelphia Public Ledger*, March 14, 1925, p. 1.
41 "Edison Company Will Remedy Causes that Hurt Radio Business," *Daily Intelligencer*, Lancaster, Pa., Nov. 17, 1924.

ABOUT THE AUTHORS

Lloyd L. Jury has been an AWA member for 39 years. He is also a member of the Tube Collectors Association and the Mid-Atlantic Antique Radio Club. Previously, he was a member of the Antique Radio Club of America.

Lloyd's first introduction to radios was in grade school, where he joined the school radio club and built a Quaker Oats box-coil-type crystal set. Later he built many other one- and two-tube sets. Lloyd served in the Army Air Force for two years during World War II and took a radio course at the Alexandria Army Air Field.

After the war Lloyd worked at the Eshelman Supply Company, a Philco distributor, for 18 years in radio/television repair service. Later he worked at Electronic Test Equipment Manufacturing Company as a technician for 23 years. Lloyd is now retired and living in Lancaster County, Pa., where he has done extensive research on historical radio topics. He is interested in making reproductions of early radio equipment and has entered three displays in AWA old equipment contests: a Bowman time receiver (1969 contest), and a complete 1922-1923 WGAL working transmitter (2002 contest). In 2004 he entered a display on the history of Dr. McCaa.

Lloyd Jury (left) shows his David McCaa AWA contest display to Ed Gable, Museum Curator..

An AWA vice president and life member and former AWA Review editor, **Brian Belanger** is also the volunteer curator of the Radio & Television Museum in Bowie, Maryland. Prior to his retirement in 2000 from the National Institute of Standards and Technology, he held several senior management positions there, including Deputy Director of the Advanced Technology Program. An electrical engineer with a bachelor's degree from Caltech and a Ph.D. from the University of Southern California, Brian was also a research engineer at the General Electric Research and Development Center early in his career. Licensed first as a ham in the 1950s (KØIUX), Brian later held other calls in regions 2 and 3. He is the co-editor of *Radio Age*, the newsletter of the Mid-Atlantic Antique Radio Club, and was the recipient of the 2001 AWA Houck Award for Documentation for his many articles on antique radio topics.

Brian Belanger

Table 1. Patents of David G. McCaa

Date	Patent No.	Title of Patent
Dec. 17, 1912	1,047,545	Apparatus for producing high-potential electrical currents
May 20, 1913	RE 13,564	Apparatus for producing high-potential electrical currents
Jan. 9, 1917	1,211,863	Apparatus for and method of producing high frequency currents of electricity
Nov. 13, 1917	1,246,626	Electric oscillator
Nov. 20, 1917	1,247,556	Apparatus for the production of high frequency currents of electricity
May 20, 1919	1,304,188	Controlling apparatus for wireless telephone systems
June 22, 1920	1,344,275	Method and apparatus for electrical communication
June 21, 1921	1,382,206	Transmitting apparatus
July 18, 1922	1,423,345	Signaling method and apparatus
Nov. 14, 1922	1,435,719	Microphone
June 19, 1923	1,459,308	Signaling apparatus
June 26, 1923	1,459,786	Method and apparatus for electrical communication
Sept. 4, 1923	1,466,912	Current relaying and production
Dec. 30, 1924	1,521,380	Receiving system
Jan. 6, 1925	1,521,777	Radio system
Jan. 6, 1925	1,522,136	Receiving system
March 31, 1925	1,531,801	Signaling system
April 28, 1925	1,535,674	Apparatus for producing oscillations
June 8, 1926	1,588,248	Antistatic system
June 22, 1926	1,589,979	Radio system
June 29, 1926	1,590,198	Radio system
June 29, 1926	1,590,635	Radio system
July 14, 1931	1,814,051	Method of and apparatus for controlling alternating current
Oct. 17, 1933	1,931,445	Method of and means for reducing the effects of undesired oscillations
May 1, 1934	1,956,689	Method of and means for reducing the effects of electrical disturbances
May 15, 1934	1,959,275	Method of and apparatus for controlling alternating currents
Aug. 7, 1934	1,969,657	Method of and means for reducing electrical disturbances
Nov. 20, 1934	1,981,457	Method of and means for reducing electrical disturbances
May 14, 1935	2,001,622	Method of and means for reducing electrical disturbances
Feb. 18, 1936	2,031,539	Method of and means for reducing electrical disturbances
Nov. 24, 1936	2,061,710	Automatic volume control (with R. D. Brown, Jr.), assigned to Philco
July 13, 1937	2,086,566	Assigned to A. N. Mann
Oct. 12, 1937	2,095,261	Assigned to A. N. Mann
Nov. 23, 1937	2,099,818	Assigned to A. N. Mann
March 29, 1938	2,112,705	Assigned to A. N. Mann
July 15, 1941	2,249,534	Static reducing device

AWA Review

CQ "Small Format" Amateur Radio Books, 1947-1984: An Annotated Bibliography

Neil D. Friedman

ABSTRACT

Books published by CQ magazine have enthused and educated Hams about the many aspects of Amateur Radio for the past sixty years. Authors have included some of the best-known experts in their fields. In this annotated bibliography, Neil D. Friedman catalogs and describes the 28 "small format" (about 6" by 9") books published by CQ between 1947 and 1984. These influential works may still be found at hamfest flea markets and online.

CQ, the Radio Amateurs' Journal, has been a prolific and influential publisher of specialized Ham Radio books from almost the magazine's founding at the close of World War II to the present day. In both influence and titles published, it ranks second in the United States only to the American Radio Relay League. Some of these works were classics in their fields that endured for many years. A number of them introduced thousands of Hams to new modes of operation and emerging topics of Amateur Radio interest. As with most publishers of substantial booklists, a few titles quickly disappeared with little effect. *CQ* book authors included some of the best known and most respected writers—*bona fide* experts—in the Amateur Radio field.

This annotated bibliography is a complete listing of the 28 "small format" (about 6 by 9 inch) *CQ* books issued through 1984. In the later 1980s, *CQ* adopted the larger (8.5 by 11 inch) format for its books that it still uses today. The books in this bibliography are listed chronologically, earliest first. Many of them, but not all, are marked as part of the "*CQ* Technical Series."

CQ published the small format books listed below through the journal's three successive New York parent companies: Radio Magazines, Inc. located in Manhattan, also published *Audio Engineering* magazine. Cowan Publishing Corp., of Manhattan and later Port Washington, Long Island, also published a number of non-Amateur Radio books and journals, including S*9* (a Citizens Band-oriented magazine). Finally, CQ Publishing, Inc., of Hicksville, Long Is-

land, owns *Popular Communications* and *CQ-VHF* magazines.

Cowan catalog entries (Cowan), Library of Congress numbers (LC), and International Standard Book Numbers (ISBN) are stated where available (consistency in numbering books or obtaining Library of Congress numbers has not been a hallmark of *CQ's* publishers). The listed prices are those either printed on the cover or, in a few cases, in contemporaneous *CQ* advertising. The present author attempted to carefully research the years of book author births and deaths and sincerely apologizes for any errors.

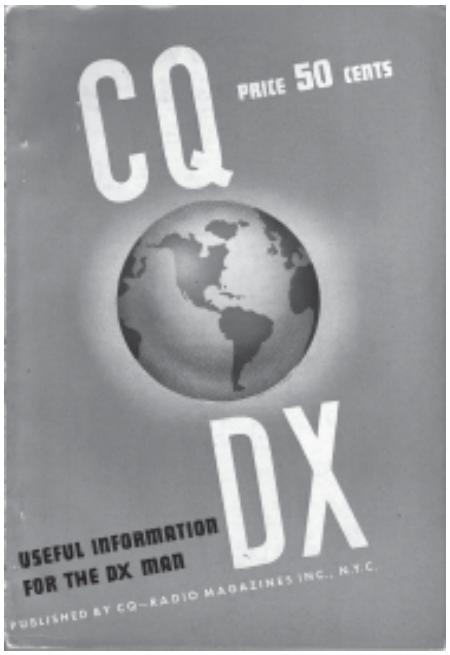
The bibliography is intended to interest and assist collectors, restorers, and others drawn to Amateur Radio history or nostalgia. The extensive advertisements in the earlier works should not be overlooked as points of interest. These books are often found at hamfests for a dollar or so. A careful search should uncover from a couple, at almost any sizable Ham Radio flea market, up to perhaps a dozen at the Dayton Hamvention. They are also available at online booksellers (such as abe.com and bookfinder.com) and on ebay at (often substantially) higher prices. In a recent online session, the present author located 15 titles in half an hour.

The author welcomes receiving reader comments and invites your suggestions, corrections, and criticisms. Please send them to n3df@arrl.net.

1940s:

1. LeKashman, Lawrence [1920-1978], W2IOP, ed. *CQ DX; Useful Information for the DX Man.* First ed. New York: Radio Magazines, 1947.

LC 47025029. 104 pp. (includes 30 pp. adverts.). First book exclusively devoted to Ham Radio DXing. Addresses operating techniques; propagation; QSLs; international time; and awards (emphasizing *CQ's* Worked All Zones program). Includes various maps and references. LeKashman, an important early *CQ* staffer who became editor in 1949, was an ardent contester and later president of ElectroVoice. No subsequent edition published (notwithstanding the "first edition" label). Typically found in heavily worn condition. Price 50 cents.



2. LeKashman, Lawrence [1920-1978], W2IOP, ed. *TVI; Television Interference—Its Causes and Cures.* First ed. New York: Radio Magazines, 1948.

64 pp. (includes 2 pp. adverts.). First book devoted to eliminating Ham Radio interference with television reception. As TV became popular in the post-war years, interference with broadcasts posed a major threat to Amateur Radio operation. Addresses television receiver and TVI fundamentals; TVI identification, elimination, and practical corrective techniques ; harmonic suppression; use of grid dip meters (a subject closely identified with the early years of *CQ*); and proper transmitter design. Many illustrations. Spine labeled "TVI Handbook." Red cover (second edition cover is yellow). Price 50 cents.

3. LeKashman, Lawrence [1920-1978], W2IOP, ed. *TVI; Television Interference—Its Causes and Cures.* Second ed. New York: Radio Magazines, 1949.

LC 50003868. 64 pp. (includes 1 p. advert.). Includes new or replacement chapters addressing shielding experiments; step-by-step TVI elimination; measuring harmonics; and a "trap box," with adjustable trap circuits that locate spurious emissions. Spine labeled "TVI Handbook." Yellow cover (first edition cover is red). Price 50 cents.

1950s:

4. Orr, William I. [1919-2001], W6SAI. *Radio Amateurs' Mobile Handbook.* First ed. New York: Cowan, 1953.

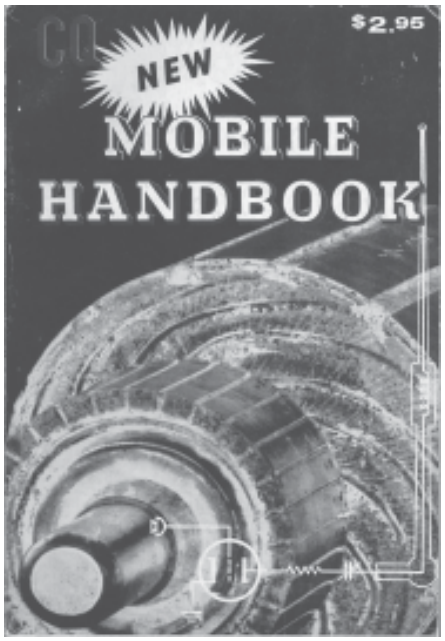
187 pp. (includes 32 pp. adverts.) plus index. HF mobiling in the AM era, with separate transmitters and receivers (or receiving converters) and vibrator/dynamotor power supplies. Addresses auto electrical systems; power supplies; receivers; noise suppression; transmitters; antennas; and test equipment. As with most Amateur Radio books from the time period, it describes relevant circuitry based largely on homebrew projects beyond the practical capability of most readers to duplicate. Available commercial equipment and operating techniques are not discussed. It would be interesting to know how a 1953 ham tuned up and zero beat a tube-type transmitter and receiver while driving. Orr was well-known for his many Amateur Radio magazine articles and columns over several decades. He wrote 20 books, including the long-lived *Radio Handbook* and *CQ's* 1996 *W6SAI Antenna Book.* Price $2.00.

5. Brown, Jack N. [1922-], W3SHY. *Single Sideband Techniques.* First ed. *CQ* Technical Series. New York: Cowan, 1954.

LC 54012654. 112 pp. (includes 17 pp. adverts.) plus index. An early overview of SSB

theory in the pre-transceiver period. Primarily devoted to description of circuit functions. Illustrated with homebrew projects. Brown was a radio engineer with experience at the National Bureau of Standards and Barker & Williamson. A contributing editor of *CQ*, his series of articles, "Getting Started in Single Sideband," introduced many amateurs to that operating mode. First use of "*CQ* Technical Series" on front cover. Cowan Publishing Corp. succeeded Radio Magazines, Inc. as *CQ*'s parent company. No subsequent edition published. Price $1.50.

6. Orr, William I. [1919-2001], W6SAI. *CQ New Mobile Handbook*. Second ed. New York: Cowan, 1956.



LC 58059925. Cowan 105. 240 pp. (includes 17 pp. adverts.). Chapters updated (from the 1953 edition) with recent projects, evidently from CQ articles. Heavily illustrated with photographs. A new chapter added addressing mobile SSB. Relatively common. Price $2.95.

7. Green, Wayne [1922-], W2NSD, *et al*, eds. *Command Sets*. *CQ* Technical Series. New York: Cowan, 1957.

LC 5859924. Cowan 106. 136 pp. (includes 20 pp. adverts.). Thousands of Hams built their stations from the flood of inexpensive surplus equipment on the market in the two decades following World War II. *CQ* found a niche publishing conversion articles in nearly every issue. This work reprints articles and short items related to the popular "Command Set" (SCR-274/ARC-5) series of aviation transmitters and receivers. Green, known for his strong editorial opinions and prescient recognition of the importance of microcomputers, was editor of *CQ* before founding 73 Magazine. Later (undated) printing adds "*CQ* Technical Series" and "No. 106" to front cover; moves price from front cover to title page; deletes names of responsible editors from title page; and adds Library of Congress number to title page. Reasonably common, but demand drives up price. Price $1.50.

8. Editors of *CQ*. *CQ Anthology; The Best of CQ 1945-1952*. *CQ* Technical

Series. New York: Cowan, 1958.

LC 5859707. Cowan 102-1. 160 pp. (includes 15 pp. adverts.). These 41 articles from *CQ*'s first eight years were, according to the preface, those most in demand as reprints by readers. Two *CQ* specialty areas are well-represented: grid dip meters and surplus conversion. The longest article, from 1948, presents an improved NBS-developed method of predicting band conditions. First printing often found with corrective cover sticker listing featured contents. Reprinted in 1962. Price $2.00.

9. Stoner, Don [1932-1999], W6TNS. *New Sideband Handbook. CQ* Technical Series. New York: Cowan, 1958.

Cowan 103. 232 pp. (includes 17 pp. adverts.). Oriented toward SSB theory, rather than the practical. Presented in a readable, largely math-free manner. The pictures and ads illustrate the force sideband had become in Amateur Radio. The preface alludes to the sometimes heated exchanges between AM and sideband devotees, but the author leaves no doubt that his own opinions are with the latter. Stoner authored multiple columns for *CQ* and wrote books on CB and marine sideband. He wrote of ham satellites as early as 1957 and AMSAT credited him as the "idea man behind Project OSCAR." A popular book with multiple printings. Price $3.00.

10. Briskman, Barry [deceased], K2IEG. *CQ Amateur Radio License Guide. CQ* Technical Series. New York: Cowan, 1959.

LC 5915266. Cowan 114. 212 pp. (includes 20 pp. adverts.). Question and answer-type study material for the Novice, General, and Amateur Extra Licenses (The Technician test was the same as the General and new Advanced licenses were not available). Also, learning the code and 80 pages of FCC rules (including CONELRAD requirements), forms, and other reference material—even rules and forms for the (then new) Citizens Radio Service. *QST* gave the book a poor review, pointing out several errors. The errors could have been easily corrected, but a license guide requires frequent updating, which ARRL did but *CQ* evidently was not disposed to do. Briskman was a *CQ* staff member and became the editor briefly in 1960. Uncommon. Price $2.50.

1960s:

11. Grayson, Kenneth B. [deceased], W2HDM, ed. *Surplus Schematics Handbook. CQ* Technical Series. New York: Cowan, 1960.

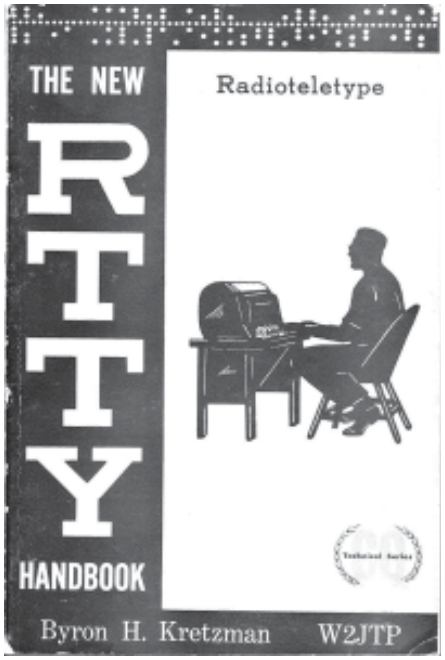
LC 59015267. Cowan 117. 112 pp. The second of three surplus conversion books published by *CQ*. This volume is 8 ½ by 11 inches—the only *CQ* book of its time period to depart from the 6 by 9 inch format—to allow for better readability of its schematic diagrams. Contains

about 90 war surplus schematics, with a paragraph or two of descriptive text for each. Grayson wrote a popular monthly column in CQ on surplus conversion. Scarce. Price $2.50.

12. Jones, Frank C. [1904-1995], W6AJF. *VHF for the Radio Amateur. CQ* Technical Series. New York: Cowan, 1961.

LC 61011995. Cowan 115. 208 pp. (includes 6 pp. adverts.). 50 through 1296 MHz in the (largely) pre-FM and repeaters era. Addresses propagation; antennas; transmitters; modulation; power supplies; converters; if systems; preamps; and test equipment. Circuit descriptions illustrated by homebrew projects, mostly AM and CW. Jones, an engineer and inventor, wrote the first *Radio Handbook* in the 1930s as well as several books on VHF and UHF Amateur Radio topics. Price $3.50.

13. Kretzman, Byron H. [1918-1997], W2JTP. *The New RTTY Handbook. CQ* Technical Series. New York: Cowan, 1962.



LC 62011836. Cowan 116. 191 pp. A practical guide to mechanical teleprinters and vacuum tube terminal units two decades before personal computers became prevalent in Amateur RTTY usage. Covers basic principles and machines; receiving equipment; transmitting equipment; setting up a station; operation; and accessories. Considered a "must own" by period RTTY operators. Kretzman was an ardent AMer and popular *CQ* RTTY columnist for many years By 1962, Cowan had dropped outside ads

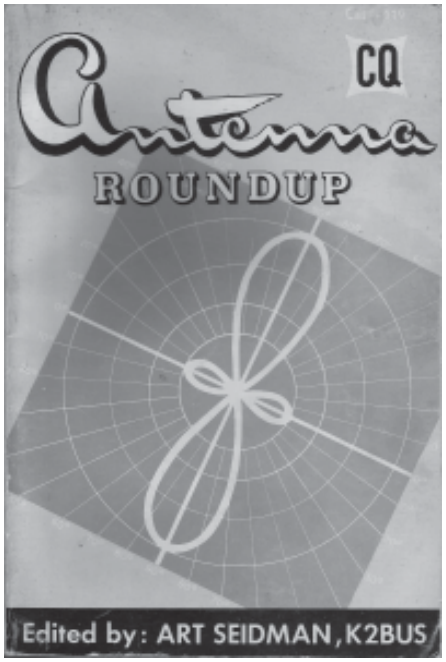
from its books. I miss them and believe they contributed to the interest in a volume. Common. Price $3.95.

14. Seidman, Art, K2BUS, ed. *CQ Amateur Radio Anthology II, 1952-1959*. New York: Cowan, 1962.

LC 58059707. Cowan 102-2. 256 pp. *CQ's* second (and last) anthology, reprinting 70 articles. Includes modification of commercial equipment (Heath DX-100, etc.), surplus conversion, and homebrew projects. No antenna articles—they were reserved for a separate volume. Includes a thirty-page history of Amateur Radio and (my favorite) "Single Sideband—Is it Really Better than Amplitude Modulation" (no, with qualifications). Also, a smattering of cartoons. Seidman, an editor of *CQ*, wrote or edited at least 15 books on radio and electronics. The present author finds these compilations interesting, although there seems to be greatly reduced need for them in an era when articles may be retrieved online or on CDs. Price $3.00.

15. Seidman, Art, K2BUS, ed. *CQ Amateur Radio Antenna Roundup*. New York: Cowan, 1963.

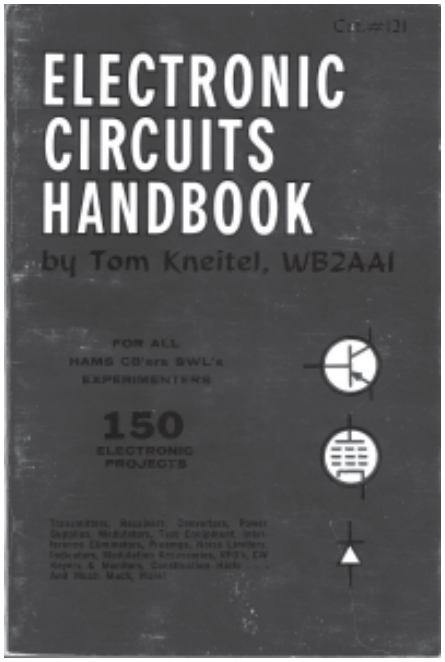
LC 63016429. Cowan 119. 160 pp. 47 antenna articles published in *CQ* in the period 1950-1961. Divided into theory; VHF; beams, quads, and horizontals; verticals and mobiles; and accessories. Includes five articles by William Orr, W6SAI. Early piece on indoor HF antennas. Antenna projects generally retain relevance and interest longer than articles in other Amateur Radio technical areas. Price $3.00.



16. Kneitel, Tom, WB2AAI. *Electronic Circuits Handbook*. New York: Cowan, 1963.

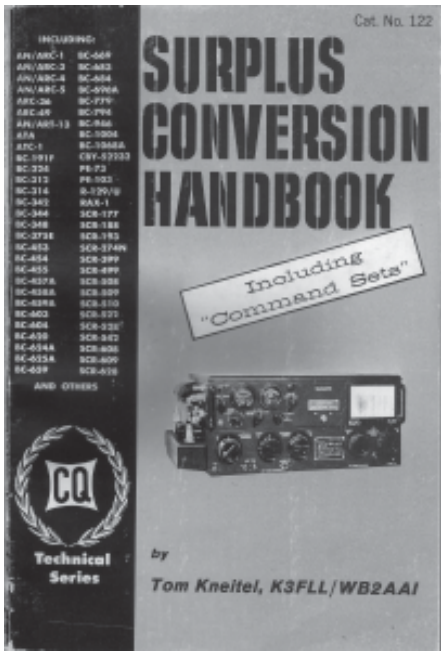
LC 63020458. Cowan 121. 126 pp. 150 projects "for all Hams, CBers, SWLs, experimenters." Mostly tube circuits with brief descriptions and schematics (but no photos). No mention of *CQ*, but the included circuits were likely to appeal to Amateurs: transmitters, receivers and accessories, modulators, power supplies, etc. First 15 pages devoted to construction techniques (got your set of chassis punches?). Circuits not attributed to any sources. Kneitel, a *CQ* editor, edited various electronic magazines and

wrote over 30 books. Orange cover (vol. II was purple). Scarce despite second (1967) printing. Price $3.00.



17. Kneitel, Tom, K3FLL/WB2AAI, ed. *Surplus Conversion Handbook, Including "Command Sets." CQ* Technical Series. Port Washington NY: Cowan, 1964.

LC 6408936. Cowan 122. 192 pp. The third and last of *CQ's* surplus conversion "how to" and reference manuals. Addresses Command Sets (reprints some articles from prior book) and many other military radios. The Forward notes that, two decades after World War II, a surplus transmitter still sold for $5.00. Begins with a useful review of surplus "lingo" and set designations (e.g., ARC-5/SCR-274). Cowan Publications moved to Long Island, New York in 1964. Price $3.00.



18. Stoner, Donald L. [1932-1999], W6TNS, comp. *Shop & Shack Shortcuts. CQ* Technical Series. Port Washington NY: Cowan, 1964.

LC 64024084. Cowan 120. 224 pp. A compilation of hundreds of brief practical ideas previously published in *CQ* as early as 1947. Similar to ARRL's popular *Hints and Kinks* collections. The shortcuts are each attributed to the original author and grouped into thirteen general topics. Tube technology predominates. Includes numerous surplus and commercial equipment modifications. Interesting reading, but apparently a poor seller. Very scarce. Price $3.95.

19. Kneitel, Tom, K2AES, ed. *Antenna Roundup*. Vol 2. Port Washington NY: Cowan, 1966.

LC 63016429. Cowan 119-2. 160 pp. 92 more (mostly brief) antenna articles. Grouped into general information; low band; verticals; VHF; towers; CB; and SWL antennas. Items in latter two chapters probably taken from Cowan publications other than *CQ*. Articles not attributed to specific authors, although prominent Amateurs are mentioned as sources in the Forward. Price $4.00.

20. Glanzer, Ken "Judge," K7GCO. *Antenna Handbook*. Vol. 1—Theory and Practice. Port Washington NY: Cowan, 1966.

LC 66014723. Cowan 123. 109 pp. Covers transmission lines; antenna fundamentals; and matching devices. The introduction states the Antenna Handbook would include three volumes, but the present author has not seen other than Vol. 1. The book's covers and contents do not mention *CQ,* which is unusual as Hams clearly comprise the intended readership. Price $4.00.

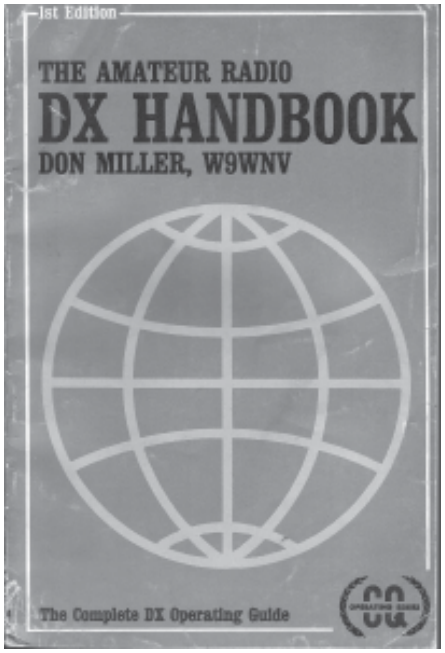
21. Kneitel, Tom, K2AES. *Electronic Circuits Handbook*. Vol. 2. *CQ* Technical Series. Port Washington, NY: Cowan, 1966.

LC 63016429. Cowan 121-2. 126 pp. 158 more projects, each briefly described. This second volume includes the *CQ* Technical Series logo on the front and its contents are more clearly Ham-oriented, with added chapters on commercial equipment modifications and VHF transmitters and receivers. Still primarily tube-type technology. Kneitel dedicates the volume to his grandfather Max Fleischer, the celebrated cartoonist. Price $3.00.

22. Miller, Don, W9WNV. *The Amateur Radio DX Handbook*. First ed. *CQ* Operating Series. Port Washington, NY: Cowan, 1968.

LC 58058737. 199 pp. Fourteen chapters cover DX propagation, equipment, techniques, and procedures. The last 50 pages are great circle bearing listings. Miller, a skilled operator and medical doctor, was a celebrated and controversial DXpeditioner in the mid-1960s. *CQ* covered his exploits

in the magazine. It then published this book at about the time that ARRL discredited certain of Miller's claimed remote island operations due to irregularities (resulting in litigation between Miller and ARRL). The book, in turn, disparages ARRL's DXCC program. Miller later served a lengthy (unrelated) prison term. The only book marked for "*CQ* Operating Series." No further editions published. Scarce. Price $5.00.



1970s:

23. Tucker, Durward J. [1906-1991], W5VU. *RTTY from A to Z. CQ* Technical Series. Port Washington, NY: Cowan, 1970.

LC: 700121207. 214 pp. A second classic radioteletype volume from *CQ*. Based on a lengthy series of articles in the magazine. A comprehensive survey of Amateur RTTY technical practice in the late 1960s. Emphasizes terminal units (modems) and frequency shift keying (FSK); teletypewriters and their adjustment; and punched-tape equipment. Tucker was an engineer and broadcast company executive. Common. Price $5.00.

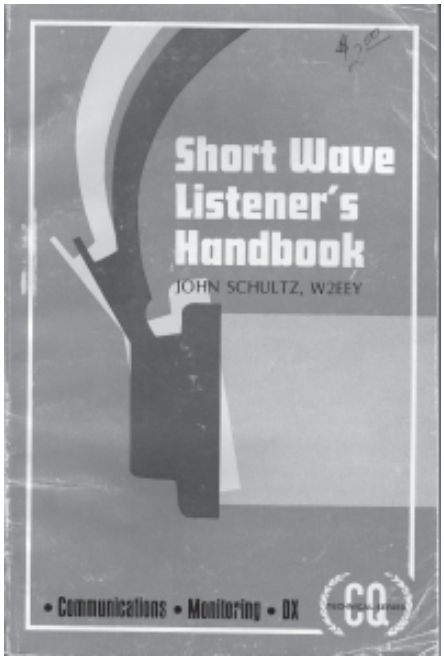
24. Lee, Capt. Paul H. [- 1994], K6TS. *The Amateur Radio Vertical Antenna Handbook.* First ed. *CQ* Technical Series. Port Washington, NY: Cowan, 1974.

LC 74083411. Cowan 129. 136 pp. Cover is subtitled *Theory, Design and Practice.* A synthesis of two decades of the author's *CQ* articles on vertical antenna topics. It is presented in twenty short chapters. Many charts and schematics, but few photographs. A little more math than the typical Amateur publication. A significant work furthering understanding of an important subject. Lee was a Navy Captain and a broadcast engineering consultant. Blue cover (second ed. with red cover is more common). Price $5.00.

25. Schultz, John [1935-], W2EEY. *Short Wave Listener's Handbook. CQ* Technical Series. Port Washington, NY: Cowan, 1975.

LC 73085837. Cowan 128. 146 pp. The only *CQ* book of this era not primarily targeted toward Radio Amateurs [although parent Cowan published non-Amateur Radio

books without the *CQ* logo]. Covers only the technical side of short wave listening. Chapters address propagation and spectrum; transmission modes; antennas; receivers; large-scale monitoring stations; suggested receiving setups; sources of transmission schedules; and test equipment. Many charts and schematics but few photographs. Schultz, an engineer and Army Reserve colonel, held management positions with Radio Free Europe, Radio Liberty, and the Voice of America. He wrote over one hundred radio articles and product reviews, mostly for *CQ*. Price $5.00.



26. Jacobs, George, W3ASK, and Theodore J. Cohen, N4XX. *The Shortwave Propagation Handbook*. First ed. *CQ* Technical Series. Port Washington, NY: Cowan, 1979.

LC 78072011. Cowan 135. 155 pp. Cover subtitled, *Principles, Theory, Prediction*. An important work in print (in various editions) for two decades. At a time when propagation forecast software had not yet migrated to home computers, Jacobs and Cohen provided a do-it-yourself prediction method based on comparing variables against furnished master charts. Equally important are the discussions of propagation principles and the sunspot cycle. Jacobs, an Amateur Radio legend, wrote *CQ*'s propagation column for over 50 years. An expert on international broadcasting, he held senior positions with the Voice of America, Radio Free Europe, and Radio Liberty. Cohen, a manager of defense-related research and development, wrote *CQ* and *Signal* columns on political aspects of Amateur Radio. Price $7.50.

1980s:

27. Jacobs, George, W3ASK, and Theodore J. Cohen, N4XX. *The Shortwave Propagation Handbook*. Second ed. *CQ* Technical Series. Hicksville, NY: CQ Publishing, 1982.

LC 82070714. ISBN 0-943016-00-2. 150 pp. plus index. Chapter on sunspot cycle predictions rewritten based on Cycle 21 high level of activity (in years subsequent to publication of first ed.). Predictive charts added and literature references

updated. A useful book index also included. The second edition may be distinguished from the first by its reddish (as opposed to yellowish) solar flare on the front cover; the words "2nd Edition" (as opposed to "1st Edition") on the upper left corner of the front cover; and the dropping of author Cohen's Citizens Band call sign (KFD-2459) from the front cover and title page. Republished by Ham Radio Bookstore in 1991. *CQ* published an updated edition, *The New Shortwave Propagation Handbook*, in larger format, in 1994. 1982 edition more common than 1979 first edition. Price $7.50.

28. Lee, Capt. Paul H. [- 1994], N6PL. *The Amateur Radio Vertical Antenna Handbook*. Second ed. *CQ* Technical Series. Hicksville, NY: CQ Publishing, 1984.

LC 74083411. 139 pp. The only apparent difference from the first ed. is a four-page addendum, "Antenna Design for 160 Meters." Still an important and useful work that remained available for sale 25 years after its initial publication. Red cover (more common than first edition with blue cover). Price $9.95.

ABOUT THE AUTHOR

Neil D. Friedman, N3DF, has written over several decades for *QST, CQ, CQ-VHF, World Radio, The AWA Review, The Old Timer's Bulletin,* and ARRL's *FCC Rule Book.* His articles range from historical topics to "A Climatological Analysis of the Dayton Hamvention" (*QST* April 1994) and "Prairie Palaces" (*CQ-VHF* April 1999), a warning about antenna restrictions in housing covenants.

Neil collects telegraph keys as well as Ham Radio publications and ephemera. In 40 years of hamfesting, including 28 Dayton Hamventions, Neil estimates that he has examined 250,000 vendor booths, tables, and spaces. He has yet to persuade the ARRL or *CQ* to issue an award on that basis.

An attorney and Certified Public Accountant, Neil is currently an Air Force budget analyst at the Pentagon.

This article was peer reviewed.

AWA Review

Television Historian: An Appreciation of George Shiers (1908-83)

Christopher H. Sterling ©2006

ABSTRACT

Though readers may not recognize his name, historical researcher and author George Shiers' valuable influence lasts to this day, more than two decades after his death. Employed in the English and (after World War II) American electrical industries in the 1940s and 1950s, he became a freelance researcher and college teacher, moving to California. An authority on electronic drafting (his book on the subject was long the standard text), he taught courses in technical writing. At the same time, he developed a valuable book collection on the history of electronics. His magnum opus, the definitive bibliography of early television development, remains a basic multilingual reference source used by anyone writing about television's technical history. His historical articles and reference books, written over a period of two decades, and especially the memorial trust he and his wife established, continue to support research efforts that add to our knowledge of radio and television development.

George Shiers was a long-time student of electronics history, focusing first on radio and eventually settling on television's development as his life work. He authored several important historical books and articles—including the definitive bibliography of television's early development. Though his work is often cited today and his estate funded several continuing legacies, too little is known of the modest man himself.

After a career in the electronics business, Shiers became a freelance technical writer and part-time college teacher who lived in California for the last 30 years of his life. I came to know and work with him when we cooperated on several historical projects in the 1970s, and what follows draws on that experience.

MAN AND METHODS

Born in October 17, 1908 in Coventry, England, Shiers was educated in London public schools from 1914 to 1922, and then took occasional evening technical courses in the years that followed. As was typical for his generation, he never attended college. He worked in Britain's electrical industry in the 15 years before World War II, though for which firms is no longer known. He married his wife May (whom he had known since childhood) in late October 1936. And shortly thereafter, they watched their first television broadcasts as the BBC inaugurated regular video programming from its North London Alexandra Palace studios. Little did Shiers then realize how important those broadcasts would become in his later life. During the war, he was an inspector, tester and supervisor of radar, radio transmitters, and

aircraft landing equipment for A.C. Cossor and then Standard Telephone and Cables.

After the war, George continued work in the fast-changing electronics business, working in England for the American Instrument Company. Living in Southgate (part of London), he was also a bookseller and library furnisher in his spare time, a vocation that included the making of bookends and book boxes. (As a hobby he made wonderful scale wooden models of various pieces of furniture, including period chairs, bookcases, and an intricate radio-phonograph console, complete with tiny wooden tubes and real wiring. A few of these pieces survive today.) Then in mid-1948—along with many others departing because of the poor economic outlook in Britain's post-war years—he and May emigrated to the United States, where the employment outlook was brighter. They settled first in Silver Spring, Maryland, in the suburbs of Washington, DC. He soon found work in the electronics business (with D&R Ltd. and then with Curtiss-Wright) which was increasingly focusing on military contracts.

May and George would move once more, this time out to Santa Barbara in 1953 (the same year he first joined the Institute of Electrical and Electronic Engineers), and they both became naturalized U.S. citizens a year later. What led to the move is no longer clear–it could simply have been about California's sunshine and lifestyle, surely understandable to a couple who grew up with English weather! George virtually hand-built, wired and plumbed substantial parts of their modern two bedroom ranch-style home perched above the town and the Pacific Ocean beyond. His library and office desk looked out onto the Pacific, and on clear days he could even see the offshore Channel Islands. A back yard brick patio was laid out by George, and fruit-bearing orange trees surrounded the house.

By 1958 George was writing on a free-lance basis, building on his contacts made over a decade of living in the States. He also began teaching part-time, first (1955-68) at the adult education center of Santa Barbara City College, and by 1967 on the staff of the University of California (Santa Barbara) Extension division. A number of his courses were taught on nearby military installations, including the U. S. Navy's air weapons station at Pt. Mugu on the California coast. His teaching centered upon the principles of good technical and scientific writing, especially the use of clear and simple words to overcome the all too common government-speak found in many companies and military facilities (Fig. 1).

By the early 1960s, George's own research and writing efforts focused increasingly on the history of electronics. He'd begun to develop an impressive personal research library on electronics history (back then, many now valuable

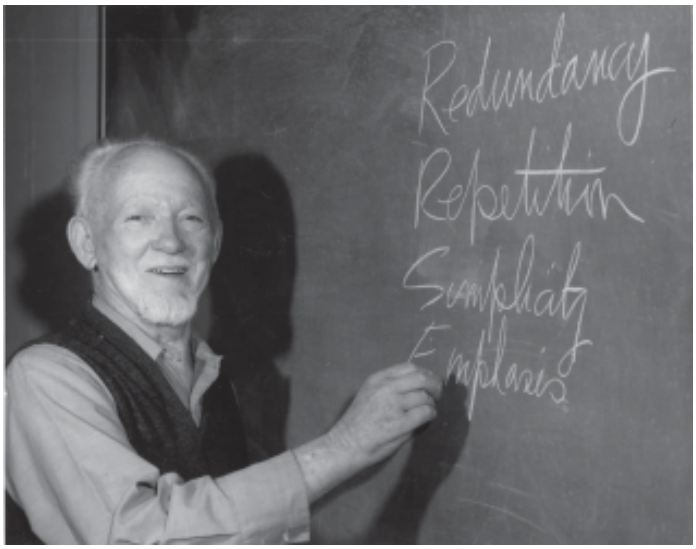


Fig. 1. George Shiers at the blackboard teaching writing style.

fitted and painted wooden desktop boxes of his own design. He spent days in major research libraries in Los Angeles and elsewhere, either copying important documents by hand, or making Thermofax impressions (some survive to this day, brown and fading) and eventually Xerox copies, all carefully pasted into notebooks divided by subject and period. George's original manuscript drafts were also hand-written, turned into clear typescript by May working with an electric typewriter. As was English and American titles could be readily found for a few dollars each), for which he designed a special bookplate that included the names of many early electrical inventors (see Fig. 2). Each title was sequentially numbered as it was added, and he kept a careful inventory of the collection. Thus one can roughly tell when a book came into his collection. (After his death, I worked with the estate's executor to inventory and evaluate that library before it was sold, and I retain the logs as well as a selection of the books, especially those on television, for reasons that will become clearer below.)

His research methods were, of course, purely analog in those days. Always working with May—they made an inseparable team—he took careful notes by hand (unlike many, his handwriting was wonderfully clear) on 3 by 5 inch sheets of paper which he neatly filed in

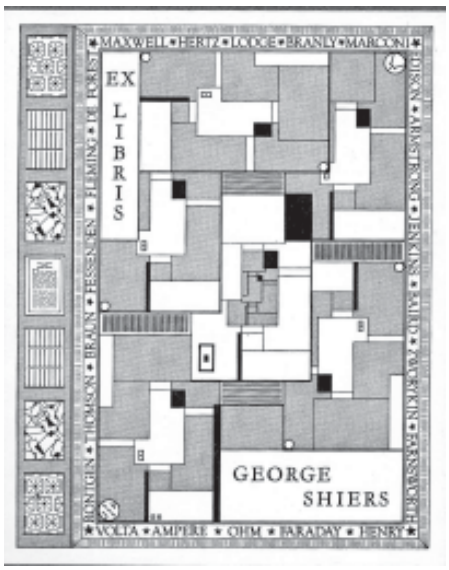


Fig. 2. George Shiers' bookplate.

typical of Englishmen of his generation, he carried on an extensive correspondence (what he could have done with email and the Internet!) with other researchers and sources. He kept detailed records of what he had learned and documented everything—he was outspoken on the need for clear tracking of all research. The Shiers made at least one trip back to England in the late 1960s, visiting friends and archives. During the last decade or so of his life, Shiers had become a corresponding friend (sadly they never met face-to-face) with former BBC Television Chief Engineer (and one-time Baird assistant) Tony Bridgewater after the latter's retirement. Bridgewater often referred to George and his historical research with considerable reverence. Otherwise, save for May, George's was largely a solitary research quest as he sought primary sources rather than relying on the secondary work of others. He was, in many ways, the epitome of the largely self-taught and highly-focused English amateur scholar, successful despite his lack of formal academic credentials thanks to the effort he put into his work over the years.

Fig. 3. Shiers at a typewriter.

Both George and May loved the central California coast they had come to call home (often driving up to nearby Solvang for the day, as but one example). Starting while still in England, over the years they had together collected what became an extensive library of early (18th and 19th century) English children's books–for which, again, George designed a special bookplate placed in each tiny volume (see Fig. 4). It was featured in several library displays in southern California before being sold to the UCLA library in the late 1970s. George also had the railway bug–that is, if they were British railways. Both May and George loved cats and there was at least one, and usually more, quietly padding about their home.

Only in late 1973 did I first become aware of George Shiers. I was then editing collections of facsimile reprints of pioneering books on radio and television and telecommunications to be republished by Arno Press (then an arm of the New York Times Co.), a firm that specialized in providing book collections for libraries. Coming across the Shiers' recent historical bibliography (see below), I

Fig. 4. George and May with some of the children's books.

wrote to him seeking advice on titles to republish, and thus began a regular and fascinating correspondence. Despite being more than a generation apart in age, we hit it off right away as we were both collectors and researchers, though his technical knowledge far exceeded mine. I first met both Shiers in August 1974 on a trip to California. For the last decade of his life, he and I were in regular contact over one historical project or another, and I was constantly learning from him. I still have much of his correspondence, all written with his neat hand—or (toward the end of his life) typed by May. The Shiers spent Christmas 1980 with us in Washington, returning to visit some of their old post-war haunts and friends. George had a twinkly sense of humor that appealed to children and adults alike. May was more serious in tone, but had a quiet humor of her own.

George Shiers was a life member of the IEEE, the Royal Television Society, and the Society of Motion Picture and Television Engineers. When he died after a long illness, aged 74, in Santa Barbara on April 23, 1983, he and May had been married for 46 years. They were devoted to one another, always mutually supportive. May died seven years later, in January 1990 when she was 75. The Shiers had no children. On her death, their estate was divided into several bequests, and though them, the work of both Shiers lives on—as is noted further below.

DRAFTING HISTORY

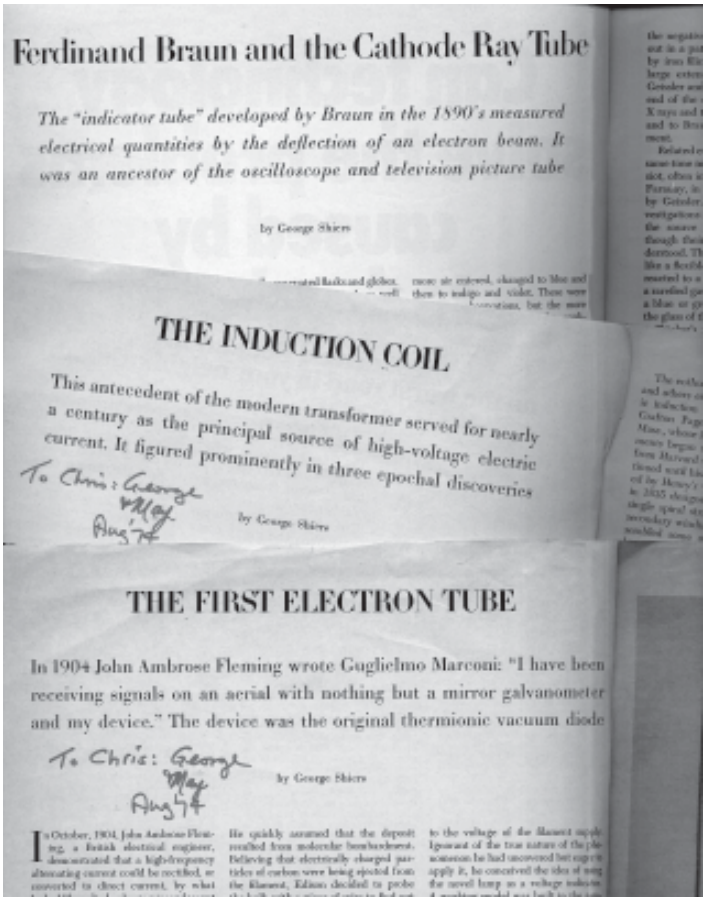
Over a two-decade period of active publishing, George authored or edited eight books and numerous articles (a full list appears at the end of this essay). His publishing career really divides into two periods—three highly-successful textbooks of the mid-1960s, followed by 15 years focused entirely on historical research into aspects of telecommunications, especially television.

He began with three college-level electronics textbooks. *Electronic Drafting* (1962) remained the standard text on the subject for years. He followed this a year later with *Electronic Drafting Techniques and Exercises* (1963), a paperback teaching supplement (with tear-out worksheets) to his main book. The early textbook trilogy was filled out with *Design and Construction of Electronic Equipment* (1966). These well-illustrated and substantial volumes all sold well, especially the first which was a market leader. Royalties from them made up a substantial part of the Shiers' income well into the 1970s (when books stayed in print longer and didn't need revisions every three years as now seems the typical pattern). As may happen with a successful book, however, the publisher and author eventually fell out when the publisher developed another book using a different author that appeared to impinge on much of what appeared in Shiers' original 1962 elctronic drafting text. The stresses of the ensuing copyright argument sadly impinged on George's health in the 1970s.

By the mid-1960s, as he was completing the last of the textbook projects, George projected writing a general illustrated history of electronic technology, outlines of which appeared in his files. Subtitled "The Development of Basic Theories, Devices and Applications in Electricity and Electronics," it would have focused on the men and efforts of the 19th and first half of the 20th centuries. Though never completed (it may not have gotten beyond the detailed outline stage), the planned book demonstrated his growing historical interests and helped to focus his future work.

Over a period of five years, George published three historical papers in the prestigious monthly *Scientific American*. The first—and George's first published foray into historical work—dealt with Ambrose Fleming's pioneering invention in 1904 of the original two-element vacuum tube ("The First Electron Tube," 1969). With clear text and diagrams he pinpointed what the English researcher had accomplished 65 years before, and how that tube provided a basis for the developing world of electrical manufacturing. His next study dealt with another vital piece of early equipment ("The Induction Coil," 1971), while the last turned to an aspect of television's history ("Ferdinand Braun and the Cathode Ray Tube," 1974). The CRT, of course, was a central device in

George's growing fascination with the early story of television. In each of these first historical articles, his clear language and descriptions, as well as diagrams, made often complex technical matters vivid for a general audience (see Fig. 5).


Ferdinand Braun and the Cathode Ray Tube

The "indicator tube" developed by Braun in the 1890's measured electrical quantities by the deflection of an electron beam. It was an ancestor of the oscilloscope and television picture tube

by George Shiers

THE INDUCTION COIL

This antecedent of the modern transformer served for nearly a century as the principal source of high-voltage electric current. It figured prominently in three epochal discoveries

To Chris: George May Aug '74

by George Shiers

THE FIRST ELECTRON TUBE

In 1904 John Ambrose Fleming wrote Guglielmo Marconi: "I have been receiving signals on an aerial with nothing but a mirror galvanometer and my device." The device was the original thermionic vacuum diode

To Chris: George May Aug '74

by George Shiers

Fig. 5. The three *Scientific American* pieces.

historical research, the *Bibliography of the History of Electronics* (1972) offered an annotated guide to a broad English-language literature. Compiled with May (she played a central supporting role in all of his writing), it included some 1,800 well-organized citations ranging from the telegraph and telephone to radio, television, computers, electronics and radar. It was designed for both libraries and collectors—and is still widely cited. A quarter century later, long after the initial edition had gone out of print, I prepared an update of the bibliography, focusing the new edition on telecommunications alone to keep the project to a manageable size, given the substantial historical record that had accumulated since the 1972 book. With some 2,500 entries, the new version appeared as *History of Telecommunications Technology: An Annotated*

George's fourth book was something quite different from the textbooks which had preceded it. This was his first book-length historical reference work, and is probably the best known of his writings to many readers of these pages. Reflecting his decade-long focus on

Bibliography (2000), coauthored by Shiers and Sterling.

In 1977, as a part of a larger series of anthologies of telecommunications history on which we worked together, George edited four volumes of important contemporary articles in *The Electric Telegraph, The Telephone, The Development of Wireless to 1920*, and, by then his true research love, *The Technical Development of Television* (all 1977). Each of these included up to two dozen papers, some well over a century old and all but impossible to find in their original form. He wrote contextual introductions for two of the volumes. Intended to help libraries fill holes in their collections, and issued in only a few hundred copies each, they have themselves become collector's items in recent years.

TELEVISION

George's magnum opus was his definitive bibliography of television's development to 1940. A project that eventually stretched over nearly 35 years, it culminated in publication only years after both George's and May's deaths.

George began his intensive study of television history in 1963, eventually publishing a number of articles on the topic while gathering annotated entries (in a variety of languages, as television developments took place in many countries) for "the book." His explorations in the by-ways of television included obtaining copies of at least the key patents here and in Britain, one result of recurrent research trips down the coast to Los Angeles libraries. He also corresponded extensively with fellow historians such as Albert Abramson (who authored several seminal volumes on television's development), and British television pioneers including Tony Bridgewater who had worked with John Logie Baird and then for BBC television.

While assembling the master bibliography, George spun off several articles. His first television article growing from this bibliographic research was "Early Schemes for Television" (*IEEE Spectrum*) which explored the pre-history of television systems, most of them mechanical in operation. "Television Fifty Years Ago" (Royal Television Society *Journal*) looked at the early work of Scottish inventor John Logie Baird. A different version of some of this material appeared as "Television 50 Years Ago" (*Journal of Broadcasting*), his only publication in an academic journal. "Historical Notes on Television Before 1900" (*SMPTE Journal*) continued his valuable exposure of the very first conceptions of what would become television. This was followed by "The Rise of Mechanical Television" (*SMPTE Journal*), the last publication to appear in his lifetime. Each of these was very carefully documented, something he felt strongly about.

By mid-1978, George had made significant progress on his television bibliographic opus and he began mailing me

"safety copies" of book chapters as they came off May's typewriter (I was then at Temple University in Philadelphia—he figured the "other coast" should be safe enough). Each one got longer as they recorded the expanding research efforts on television during the 1920s. He had completed 11 chapters—taking the story through 1931—by the time of his death. And he had already made entry reference slips for most of the material to follow, though he hadn't written them up or done chapter introductions tying them together. As his health began to fail, he realized he would not be able to finish the work himself. After an attempt to find a local writer to carry on the project failed, I committed to seeing the bibliography through to publication—never imagining it would take 14 years to make good on that promise.

There were four problems standing in the way of the book's publication on George's death. Obviously, the volume was incomplete, though George had sketched out much of the content and many of the specific entries right up to 1939. One or more people to complete, edit, and index the book had to be found. Funding to pay for this expertise was vital. And we lacked a publisher–George had never sought one until he had more to show. The funding eventually came from several sources, including a grant from an old friend of the Shiers, another from the IEEE Life Members Fund, an advance from a publisher, and others. But the central "find" was the key people to make the project happen. Elliot Sivowitch, then a museum assistant in the division of electricity and modern physics at the Smithsonian's Museum of American History, was the vital cog who knew television history, and in turn led us to technical editor Diana Menkes who completed the massive editing and indexing of the final book which contained nearly 9,000 entries in several different languages. Many others helped in a variety of ways. After a decades-long gestation, the more than 600-age book finally appeared in print as *Early Television: A Bibliographic Guide to 1940* (1997).

A well-thumbed copy of the television bibliography (for which Bridgewater provided a foreword), and George's earlier electronics bibliography have become vital tools for researchers. That the magnum opus includes materials in many different languages helped to underline the multi-nation background of television, and it has greatly assisted researchers in taking a broader look at the medium's development. As television historian Russell Burns noted in a communication with me early in 2006:

> George Shiers's *Early Television* is a major resource for television historians. . .a mine of information and an exemplar of how such guides should be compiled, structured, commented upon, and indexed. First, his coverage of the period of early television is comprehensive. No popular, or semi-

popular, or scholarly magazine, or journal, or periodical seems to have been overlooked. Shiers has identified his sources with meticulous accuracy. Secondly, he has grouped his citations into chapters which have a natural coherence. Thirdly, his brief summaries/descriptions of each reference are most helpful, and his essays on the discoveries/inventions/events of certain periods will be invaluable to any inexperienced researcher. Of particular merit are the subject and name indexes which enable cross - references to any specific topic to be easily and quickly obtained.

CONTINUING THE SHIERS LEGACY

On May Shiers' death in 1990, the Shiers' estate was divided into seven parts, including two to family relations and a small bequest to the Santa Barbara humane society ("applied solely for the care and welfare of cats"). Among the other bequests were those to support a lecture series and the purchase of books at City College in Santa Barbara (where George had taught for so many years), and the University of California Santa Barbara Foundation, for "the restoration or purchase of books on the history of engineering and technology."

A grant to George Washington University has helped to fund "research and related activities concerning any aspect of television and associated technologies including history of the art and science, technical and public developments in broadcasting, telecommunications policy, publications, seminars and other public meetings." Among projects supported have been a research workshop on the development of undersea telegraph cables, underwriting the twice-yearly publication of *Antenna* (the publication of the Mercurians group of communications historians, a part of the Society for the History of Technology), faculty research and travel, student research support for various studies; exhibits at the Museum of Radio and Television just outside of Washington, and the purchase of relevant books and research materials.

Best known of the grantees is surely the Shiers Memorial Trust of the Royal Television Society in London. After clarification of legalities and purpose in the original bequest, the Trust was established and has made a research award related to television history each year since 1999. The objective of the trust is "the promotion of public education through the study and research of the history of television in all its aspects and without regard to country or origin, including the development and encouragement of publications and associated projects such as bibliographies and monographs on particular aspects." Applications are usually submitted by March of each year on forms available from the archivist of the Society. Of the seven grantees thus far, topics have included the development of television drama in the 1970s, a his-

tory of a British documentary series, work on the television archives of Alexandra Palace, support for an anthropological television series, research into the earliest years of television, Don McLean's two-CD presentation on the beginnings of British television, and a biography of the first head of BBC news and current affairs.

George Shiers was a man of many talents and his historical research remains valuable to scholars to this day. He helped to lay the groundwork for further historical study taking place today. His focus on the earliest days of television development helped to transform our understanding of that medium's long history. He helped many others in their own research efforts, thus acting as a mentor. And his bibliography of television history to 1940 is a monument to his dogged pursuit to create as full a record as possible. The late George Shiers has provided researchers, writers, and others with the definitive bibliography on early television. Let us hope that other workers can be stimulated to follow his example and provide scholars with similar bibliographies on related branches of the history of science and technology. Others should and will be grateful for his efforts for years to come.

THE PUBLICATIONS OF GEORGE SHIERS, 1962-2000

(These appear chronologically, books followed by chapters and periodical articles.)

BOOKS

Electronic Drafting. Englewood Cliffs, NJ: Prentice-Hall, 1962. 556 pp.

Electronic Drafting Techniques and Exercises. Englewood Cliffs, NJ: Prentice-Hall, 1963, 61 pp. plus 100 working assignments, paperback.

Design and Construction of Electronic Equipment. Englewood Cliffs, NJ: Prentice-Hall, 1965, 362 pp., with separate *Answers to Questions* booklet for instructors, 32 pp.

Bibliography of the History of Electronics (assisted by May Shiers). Metuchen, NJ: Scarecrow Press, 1972, 323 pp. About 1,800 annotated entries.

The Electric Telegraph: An Historical Anthology. (Editor and introduction.) New York: Arno Press "Historical Studies in Telecommunications," 1977, reprinting 18 papers from 1859 to 1948, ca 600 pp.

The Telephone: An Historical Anthology. (Editor.) New York: Arno Press "Historical Studies in Telecommunications," 1977, reprinting 23 papers from 1877 to 1968, ca 600 pp.

The Development of Wireless to 1920. (Editor.) New York: Arno Press "Historical Studies in Telecommunications," 1977, reprinting 20 papers from 1890 to 1920, ca 600 pp.

The Technical Development of Television. (Editor and introduction.) New York: Arno Press "Historical Studies in Telecommunications," 1977, reprinting

34 papers from 1912 to 1970, ca 600 pp.

Early Television: A Bibliographic Guide to 1940 (assisted by May Shiers, edited and indexed by Diana Menkes). New York: Garland Publishing, 1997, 616 pp. Nearly 9,000 citations, most of them annotated.

History of Telecommunications Technology: An Annotated Bibliography (with Christopher H. Sterling). Lanham, MD: Scarecrow Press, 2000, 333 pp. Some 2,500 entries

CHAPTERS AND ARTICLES

"Electronic Drawings," in W. J. Lazadder, *Fundamentals o Engineering Drawing*. Englewood Cliffs, NJ: Prentice-Hall, 1965.

"The First Electronic Tube," *Scientific American* (March 1969), pp. 104-112.

"Early Schemes for Television," *IEEE Spectrum* (May 1970), pp. 24-34. Reprinted in the *Proceedings of the Australian Institute of Electrical Engineers* (December 1970), pp. 507-416.

"The Induction Coil," *Scientific American* (May 1971), pp. 80-87.

"On the Origins of Electron Devices," *IEEE Spectrum* (November 1972), pp. 70-76.

"Ferdinand Braun and the Cathode Ray Tube," *Scientific American* (March 1974), pp. 92-101.

"Television 50 Years Ago," *Journal of Broadcasting* 19:287-400 (Fall 1975).

"Television Fifty Years Ago," *Royal Television Society Journal* (January/February 1976), pp. 6-10.

"Historical Notes on Television," *Society of Motion Picture and Television Engineers Journal* (March 1977), pp. 129-137.

"The Rise of Mechanical Television, 1901-1930" *Society of Motion Picture and Television Engineers Journal* (June 1981), pp. 508-521.

ABOUT THE AUTHOR

Christopher H. Sterling is a professor of media and public affairs at George Washington University, where he has taught since 1982. A longtime AWA member, he co-authored *Stay Tuned: A History of American Broadcasting* (Lawrence Erlbaum Associates, 2002, 3rd ed.) among nearly 20 other books and a host of articles and reviews on electronic media and telecommunications. For further information, see www.ChrisSterling.com

My sincere thanks to Doug Pennisten (Oklahoma) who first urged me to write this profile and then offered useful commentary on early drafts; to Don McLean (London) for useful comments and assistance in learning more about the Royal Television Society's Shiers Trust; to Clare Colvin (London), archivist of that Society, for further information on Trust policy and awards; to Kenneth Harwood (Santa Barbara) for aid in contacting two local recipients of Shiers bequests.

AWA Review

E.H. Scott Serial Numbers: An Updated Analysis

Kent King and Norman Braithwaite
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ABSTRACT

E. H. Scott produced a highly collectible line of radio sets during the 1930s and 1940s. Scott sets had unique serial numbers, which changed in format and value through the years. Efforts to collect and analyze serial numbers began over 30 years ago. The Internet has permitted much wider communications among collectors and has allowed the authors to collect well over 1000 serial numbers. This volume of accurate data has permitted a more thorough analysis, including estimates of numbers of sets produced. This article describes the serial number systems used by Scott and the resulting patterns in set production from 1932 to 1947. Understanding the serial number assignments allows owners to determine models of unknown sets and even estimated production dates of some models.

One of the greatest radio mysteries of the 1930s was not broadcast on the air and has taken well over half a century to unfold. Interest in this mystery was nearly non-existent at the time it developed and has become of greatest interest to radio historians and collectors during recent years. What great radio mystery could have been ignored during the golden age of radio and of interest when radio plays second fiddle to television, computer games, and the Internet? The production totals of the Stradivarius of Radio, the receivers of the E.H. Scott Radio Laboratories.

The mystery lies in the fact that, unlike most other radio companies, the E.H. Scott Radio Laboratories assigned serial numbers that did not easily disclose the number of receivers manufactured and records of the laboratories have never been found. Starting in 1932, these serial numbers consisted of a single letter followed by two or three digits and were not assigned in a very logical order. Sometime near the beginning of 1938, the serial numbers were changed to a pair of identical letters followed by two or three digits. It is very likely that this system of serial numbers was used to deliberately prevent potential competitors from learning Scott's production thereby making economic decisions leading to competing lines of receivers more difficult and risky. Today the interest in these unusual serial numbers has nothing to do with competition and everything to do with production of these scarce and desirable classic radio receivers.

The quest for an answer to the mystery took root almost 30 years ago. J.W.F. Puett, a longtime Scott authority, began gathering serial numbers in the 1970s. He published these lists periodically, and searched for patterns in the numbers. In 1992, the E. H. Scott Historical Society (EHSHS) was formed and the serial number gathering and analysis was revived. By 1998, a pattern had begun to emerge in the sets with single letter prefixes (sets produced through mid-1937, including the Allwave AW12, AW15, AW23 and some early Philharmonics). Articles appeared in the EHSHS Scott News and in the AWA Review, Volume 11, 1998. In recent years, the Internet and eBay have been a boon, as more numbers are gathered from sets posted on the web. To date, the database includes serial numbers for 500 double letter prefix sets and 600 single letter prefix sets, a total of 1100 sets.

EARLY (SINGLE LETTER PREFIX) SETS

Until the introduction of the Allwave 12 Deluxe sets in 1932, little can be inferred from the few serial numbers found on Scott receivers. The Shield Grid 9 sets had a paper tag with a serial number stamped on it. These tags are often missing, but can sometimes be found inside the IF container. The AC-10 sets had a serial number tag on the tuner and amplifier/power supply chassis. There are not enough samples of the AC-10 numbers to infer anything about production of these sets. The numbers do appear to be sequential however; lower numbers are clearly earlier versions of the AC-10. The first chrome chassis, the Allwave 12 "two-dial" set released in 1931 does not have a serial number tag on the chassis. Instead, some sets will have a grease pencil number written on the underside (inside) of the chassis. It is not clear that this is even a serial number, as not all sets have a number. In 1932, the Allwave 12 Deluxe began a consistent pattern of serial numbers for Scott set production.

The pattern in the single letter prefixes has held up well over time, and new serial numbers reinforce and clarify this numbering plan. Table 1 shows the prefixes and ranges of numbers for the Allwave series (12, 15 and 23) sets:

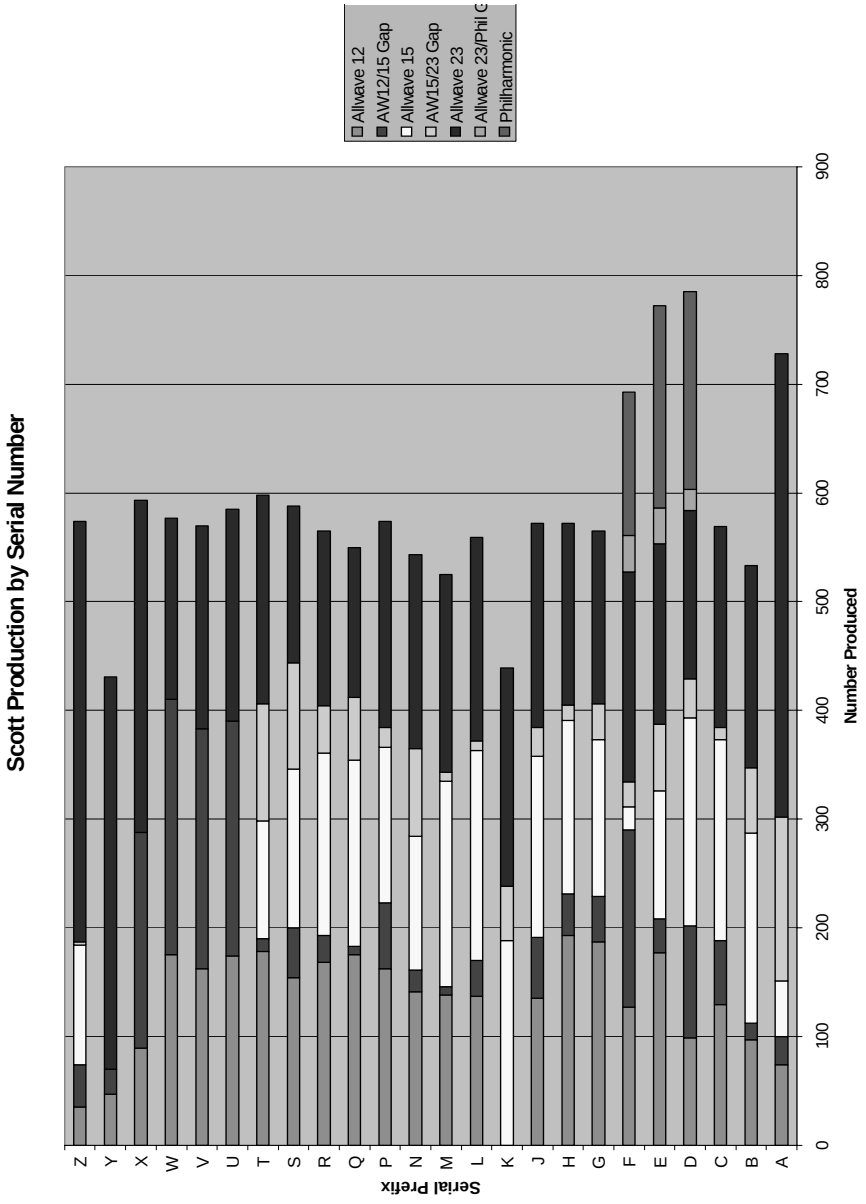
Production is sequential within a series, but the numbers do not necessarily correspond across two or more series. Thus, A-200 (AW12) may not be the same as Z-200 (AW15), but we can say that Z-50 will be earlier than Z-200. For each range, the lowest and highest known serial numbers are given. The columns labeled "AW12 C", "AW15 C" and "AW23 C" indicate the count of sets in each range. Thus the "count" columns represent production total by model for *known* serial numbers. From this, we see that the AW23 was the largest pre-1938 production set followed by the AW12 and then the AW15. The columns labeled "Gap" represent the gaps between the highest previous set and the lowest following set. As

Table 1. Allwave sets by serial number.

Prefix	AW12 L	AW12 H	AW12 C	Gap	AW15 L	AW15 H	AW15 C	Gap	AW23 L	AW23 H	AW23 C	Gap	PHIL L	PHIL H	PHIL C	Total
A	156	229	74	26	256	306	51	151	458	883	426					551
B	149	245	97	15	261	435	175	60	496	681	186					458
C	70	198	129	59	258	442	185	11	454	638	185					499
D	53	151	99	103	255	445	191	36	482	636	155	19	656	837	182	627
E	74	250	177	31	282	399	118	61	461	626	166	33	660	845	186	647
F	121	247	127	163	411	431	21	23	455	647	193	34	682	813	132	473
G	56	242	187	42	285	428	144	33	462	620	159					490
H	55	247	193	38	286	445	160	14	460	626	167					520
J	70	204	135	56	261	427	167	26	454	641	188					490
K		-1	0		254	441	188	50	492	692	201					389
L	82	218	137	33	252	444	193	9	454	640	187					517
M	108	245	138	8	254	442	189	8	451	632	182					509
N	93	233	141	20	254	376	123	81	458	635	178					442
P	73	234	162	61	296	438	143	18	457	646	190					495
Q	71	245	175	8	254	424	171	58	483	620	138					484
R	75	242	168	25	268	435	168	43	479	639	161					497
S	55	208	154	46	255	400	146	98	499	642	144					444
T	52	229	178	12	242	349	108	108	458	649	192					478
U	66	239	174	216		-1	0		456	650	195					369
V	70	231	162	221		-1	0		453	639	187					349
W	69	243	175	235		-1	0		479	645	167					342
X	57	145	89	199		-1	0		345	649	305					394
Y	190	236	47	23		-1	0		260	620	361					408
Z	64	98	35	39	138	247	110	3	251	637	387					532
			3153				2751				5000				500	
																11404

sets are found in each prefix within these gaps, the number of missing sets is reduced. Finding an AW12 set with a K prefix, or AW15 sets with prefixes of U, V, W, X or Y would add significant information to this table and the analysis. Fig. 1 gives production numbers by prefix:

Fig. 1. Production numbers by prefix.



LATE (DOUBLE LETTER PREFIX) SETS

Use of the double letter prefixes probably began late in 1937, and may coincide with the introduction of a second receiver produced at the same time. Up to this point, Scott had only offered a single model with a choice of cabinets. With the introduction of the Sixteen, Scott started building multiple receiver offerings at the same time. It is possible that this change sparked the introduction of the double letter prefixes. Production patterns in the double letter prefixes are similar, with chronological sequences within each prefix. However, we also see blocks of like sets built in a certain prefix or group of prefixes. For example, the Super XII sets all have prefixes of QQ, TT or WW, and appear together in a block of numbers in each prefix. Other blocks include JJ (Scott Special), and HH (FM Tuners). Some prefixes appear to only include one model, for example: PP is all Phantom sets and RR is entirely Philharmonic sets. Table 2 shows the later serial numbers by set.

Again, the "count" columns represent production tallies for each model and prefix for known serial numbers. The columns labeled "Gap" represent gaps between set types. Because the next model in a given prefix may not always be the same (in TT, the Super 12 is followed by a block of Phantom sets, but in WW, the Super 12 sets are followed by a block of Laureate sets), the gap number is calculated to the next sequential serial number.

TOTAL SET PRODUCTION ESTIMATES

Total production numbers for the Philharmonic include the single letter prefix sets, making it the 3rd highest produced Scott receiver. The Phantom and the Sixteen/Eighteen follow behind for highest production in the double letter sets. A combined tally of estimated production is shown in Fig. 2.

While the missing sets in the gaps between the prefix ranges still represent the 2nd highest tally of serial numbers, we have a statistically relevant sample size. Using the database of just over 1000 serial numbers, we can estimate the number of each model produced by counting the possible serial numbers within each range and set type. Thus the sample of known serial numbers represents between 4 and 5% of the extrapolated data (see Table 3).

Unlike the gaps between models, the gaps at the top and bottom of all ranges are not included in the tallies. We could assume that all numbering started at 10 for each prefix, but there is no evidence to support this. However, it is safe to say that Scott produced approximately 25,000 sets in the period between 1932 and 1941. This works out to 2,500 sets per year on average, or 10 sets per working day.

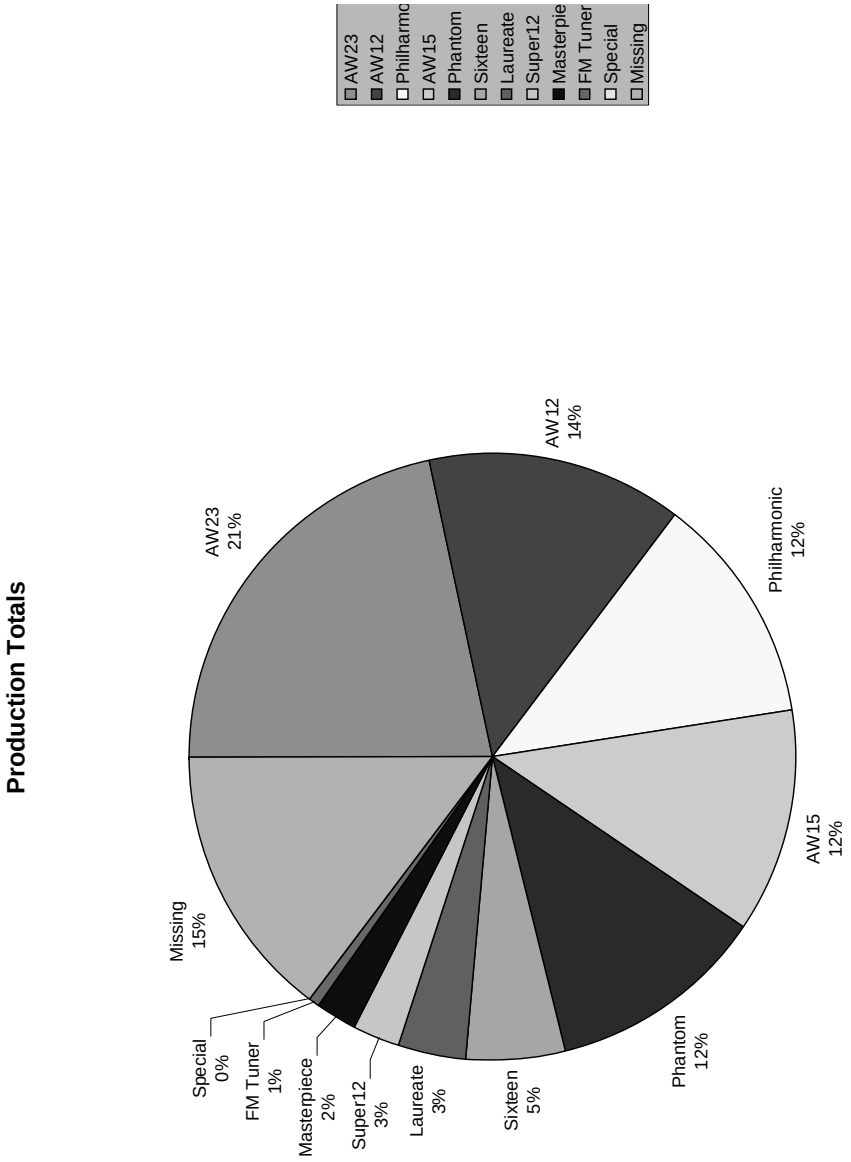
This analysis is not without a few oddities. Mistakes have been found, especially in

Table 2. Late (Double Letter Prefix) Sets

Prefix	16/18 L	16/18 H	16/18 C	Gap	S12 L	S12 H	S12 C	Gap	Phan L	Phan H	Phan C	Gap	Phil L	Phil H	Phil C	Gap	Mast L	Mast H	Mast C	Gap	Lau L	Lau H
AA									282	490	209		12	245	234	36						
BB													19	490	472							
CC	11	234	224	26					261	444	184	14	459	484	26							
DD	99	227	129	47					275	485	211											
EE	57	242	186	70					313	432	120											
FF																					304	410
GG	67	237	171	17									255	489	235							
HH	13	244	232	70																		
JJ	12	242	231	8													311	493	183			
KK									261	480	220		10	242	233	18						
LL													22	462	441							
NN	14	86	73	34					121	220	100	34					255	390	136			
PP									51	485	435											
QQ					41	241	201	39	281	499	219											
RR													15	497	483							
SS									128	486	359											
TT					24	204	181	126	331	473	143											
UU									21	152	132	0									153	374
WW					10	222	213	31													254	493
XX									155	241	87	24	15	120	106	34					266	495
YY									15	224	210	45	270	396	127							
ZZ									268	487	220						52	236	185	31		
			1246				595				2849				2357				504			

Note: The FM Tuners and Special Communications Sets are not shown. The FM Tuners are between HH-315 and HH-446, and the Special Communications receivers are JJ-251 to JJ-271.

Fig. 2. Production totals



the serial numbers gathered in the early days. It is not uncommon to find an AW15 listed as an AW12 (there are 12 tubes on the AW15 tuner chassis). Over the years, some serial number tags have been interchanged on sets, creating additional confusion. The NN prefix has a mixture of sets with serial numbers below 200, but all NN sets above 200 are Masterpiece sets.

Based on these numbers, and knowing the Scott sales volumes (in dollars) for each year through the 1930's, sales esti-

Table 3. Production totals estimated from known serial numbers

Set	Count
AW23	5000
AW12	3153
Philharmonic	2857
AW15	2751
Phantom	2685
Sixteen	1246
Laureate	799
Super12	595
Masterpiece	504
FM Tuner	132
Special	21
Missing	3399
Total Sets	19743
Grand Total	**23142**

mates can be created. To develop these estimates, an average value was assigned to each model. Obviously, some sets were higher than the average (extreme high-end cabinets, the Quaranta sets, etc.), and some lower (price slashing sales, end of production sales). For the purposes of the sales volume analysis, the following average values were used: AW12 and AW15: $240; AW23 $275; Philharmonic $410 and all other models $240.

Table 4 – Production Related to Sales is shown on the page opposite. The estimated sales based on these values falls within ½ of 1% for each year where sales figures are known. For 1940 and 1941, these same figures provide estimated sales of just over ½ million dollars. The difference between the Estimated and Actual numbers is due to the missing sets in the gaps between models. The numbers should converge as more sets are found and the gaps are reduced. The production counts track the serial number data closely, providing additional verification of the estimates.

THE POST WAR ERA

The E.H. Scott Radio Laboratories emerged from World War II a different company. Management of the company was taken over by Hal Darr, Scott's trusted accountant, during an extended visit by E.H. Scott to New Zealand. The company name was changed to Scott Radio Laboratories, Incorporated. Capitalization was substantially increased through a large stock offering, product sales were through distributors such as upscale furniture stores instead of direct mail order, and the serial numbers were for the most part assigned in sequential order. As the E.H. Scott Radio Laboratories had done prior to 1937, the new company again adopted the practice of manufacturing one receiver model at a time and offering it with several cabinet and accessory options.

Another change from the prewar era was the practice of date stamping the receivers before leaving the factory. On the 800 series receivers, date stamps can nearly always be found in the lower left corner of the station preset shroud (looking from the front of the tuner chassis with a flashlight) and on the top side of the tuning motor laminations (requires re-

moval of motor for inspection). Some 800 series receivers have been found with a date stamp located on the backside of the dial support bracket. The combination of sequential serial numbers with date stamps provides considerable production information from a relatively small sample of collected serial number and date stamp data.

Table 4. Production related to sales

Year	Sales	AW12 Prod	AW15 Prod	AW23 Prod	Phil Prod	Other	Est Sales	
1932	408000	1700					408000	
1933	482000	2000					480000	
1934	568000	300	2075				570000	
1935	690000		700	1900			690500	
1936	786000			2860			786500	
1937	780000			500	1200	625	779500	
1938	521000				600	1150	522000	
1939	685000				625	1785	684650	
1940					500	1500	565000	
1941					500	1500	565000	
Total		4000	2775	5260	3425	6560	22020	Total
Estimated		3784	3026	5500	3143	6871	22496	23404
Actual		3153	2751	5000	2857	5875	19632	

Based on a sample of 16 serial numbers with associated date stamps, production of the 800 series chassis began around January 1946 with the first receivers completed on February 1, 1946. Assuming all serial numbers were assigned, the 9000th series 800 receiver was completed near the middle of June 1947 and total production of the 800 series receivers probably did not exceed 9,500. Plotting these serial numbers against the date stamp, Fig. 3 indicates an initial production rate of approximately 25 receivers per working day until mid August 1946. Production for the next two months dropped to approximately 15 receivers per working day during which time it appears the company may have been upgrading equipment or tooling for increased production. From mid October 1946 through mid April 1947 the company produced approximately 35 receivers per working day followed by a production rate of approximately 10 receivers per working day until production on the 800 series receivers ceased sometime after June 1947. This later decrease in production was likely related to decreasing model sales combined with

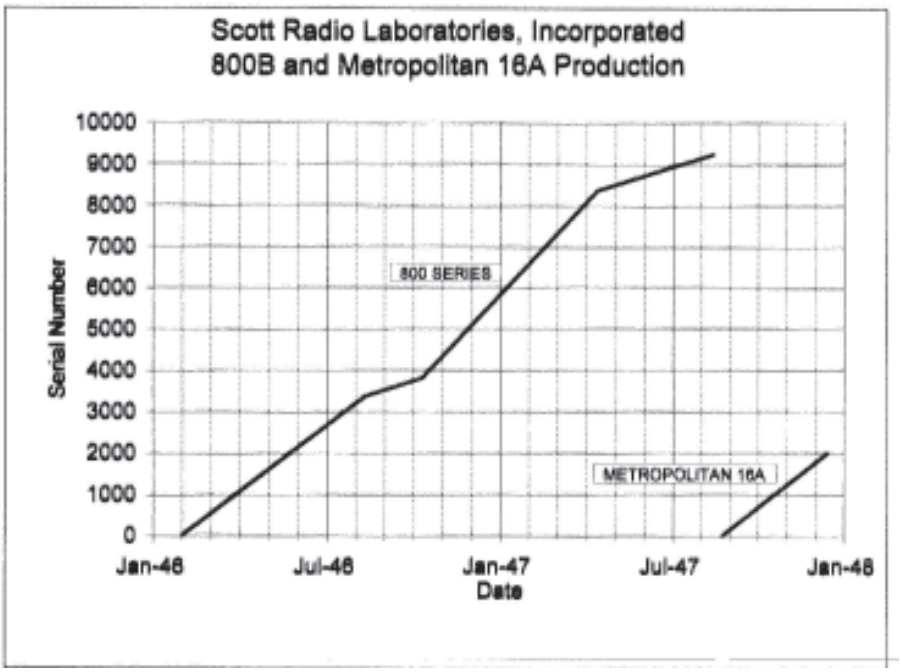


Fig. 3. Production rates for 800B and Metropolitan sets

a need to retool for production of the next model.

Following the 800 series receiver, the Scott Radio Laboratories, Incorporated offered the Metropolitan 16A, a similarly styled high fidelity receiver without shortwave reception or motor operated tuning. Date stamps on the Metropolitan 16A receiver can be found on the back of the dial support bracket immediately to the right of and partially behind the tuning capacitor shield (looking from the back of the tuner chassis). From limited serial number and date stamp data collected for this model, production appears to have started around July 1947 with the first receivers completed in mid to late August 1947. Production of the Metropolitan 16A exceeded 25 receivers per working day through late November 1947 when the total exceeded 1600 receivers. Production of the Metropolitan 16A receiver is likely to have ceased near the end of 1947 with fewer than 2000 total receivers completed.

Although the serial number and date stamp data indicate production of the 800 series receiver ceased around June 1947 and of the Metropolitan 16A receiver ceased around the end of 1947, both models appear to have been offered for several years thereafter. Some of the 800 series receivers have been found in large combination consoles with television sets having 20-inch or larger rectangular picture tubes that were not available until 1951 and both receivers have been

found with Webster Chicago model 357 three-speed record changers manufactured well after 1947. Also, a small number of the 800 series receivers have serial numbers in the 17,000s.

In spite of their high serial numbers these few 800 series receivers have mid 1947 date stamps. One 800 series receiver having a serial number of 17666 and a date stamp of July 1, 1947 also has the number 8923 handwritten and upside down on the back of the dial support bracket. The date stamp is reasonably consistent with the handwritten number indicating a strong probability that the 800 series receivers having serial numbers in the 17,000s were receivers that were originally assigned lower serial numbers and subsequently assigned higher serial numbers when modified, included in a special cabinet or installation, or sold at a later date. Whether or not a serial number in the 17,000s was assigned, it is clear that the Scott Radio Laboratories, Incorporated manufactured and stored a number of extra 800 series and Metropolitan 16A chassis for later sales, incorporation in television combinations, and possibly for special installations.

From this analysis it is clear that the E.H. Scott Radio Laboratories and Scott Radio Laboratories Incorporated produced a total of approximately 36,000 receivers for the civilian market from 1932 through 1947. Of these, approximately 2/3 were manufactured prior to WWII at an average production rate of 10 receivers per working day and 1/3 were manufactured in 1946 and 1947 at a production rate averaging 24 receivers per working day. One of the most interesting lessons from this analysis is the fact that some of the least common classic Scott receivers are the lesser models of the late 1930s that are often overlooked by collectors as being less significant. These include the Super 12, Masterpiece, and Laureate. It is also interesting to note that the most elaborate and costly standard offering, the postwar 800 series having remote ready pushbutton motor tuning and FM on all receivers, was the highest production model. Finally, after well more than half a century and with the cooperation of many radio historians and collectors who have shared serial number data, we have substantially solved one of the greatest and longest-lived mysteries of radio.

ABOUT THE AUTHORS

Kent King has been a radio collector since 1976 and has specialized in E. H. Scott sets since 1985. The collection is focused on different models and chassis, and is probably one of the most diverse Scott collections in existence. The collection spans more than two decades and contains over 50 different models and chassis. Kent especially enjoys battery sets, including those from the 1920s and the chrome 2-volt and 6-volt sets of the 1930s. The collection also includes many postwar examples, including a half dozen sets produced under the Scott name following the bankruptcy in 1956. Besides radios, Kent is the Director of Information Security for a central Ohio insurance company and owns a 10 acre alpaca farm with his wife Michele and sons Matthew, Ryan and Michael.

Kent King

Norm Braithwaite

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AWA Review

Techniques of Radio Intelligence in the Second World War

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ABSTRACT

Radio Intelligence is the analysis of the enemy's radio signals to determine his capabilities, intentions, disposition and order of battle. It consists of **Cryptography, Direction Finding, Traffic Analysis, and Radio Fingerprinting.** The technique of radio intelligence was born in the First World War, the world's first scientific-industrial war. By the end of the war in 1918 the use of wireless was so deeply entrenched that its use in future military operations was assured.

CRYPTOGRAPHY

In Germany the Enigma encoding machine was perfected in the 1930s and thought to be unbreakable. Polish mathematicians immediately attacked the system and made considerable progress. On the eve of war, the Poles turned their findings over to the French and British who then built upon this information. The eventual result was "Ultra", the flow of decripted German messages (Winterbottom 1974). Cryptography already had a centuries-old history as detailed by Kahn (1968). As such it had direct applications to wireless. One of the well known weaknesses of wireless is the ability of anyone (the enemy) to listen to the traffic. Because a prudent commander will assume that the enemy always monitors all of his wireless transmissions he will or should attempt to limit his transmissions as much as possible and to encode the transmissions he does send.

Perhaps the best example of the consequences of not encrypting wireless transmissions happened during the battle of Tannenberg on the Eastern front (Kahn, 1983, p 26, 101). In the preparatory stages of this landmark battle, the German army was facing a much larger contingent of Russian forces near Tannenberg. The Russian armies were the victims of widespread graft, corruption and general unprofessionalism that was endemic in the Czar's military. As a result, the Russians had only a tiny fraction of the amount of field wire needed for their landline communications. The Czar's forces were therefore compelled to use wireless. The same shortcomings resulted in most of the Russian forces not having been issued the proper codes to use. Shortly be-

fore the battle, the Russians sent orders and directions to subordinate commands by wireless. These transmissions were sent in the clear and were copied by the Germans who now knew the Russians intentions and order-of-battle: a priceless opportunity for a military commander.

Fig. 1. German Navy 4-rotor Enigma. Tom Perera's Enigma Museum.

As a result, the German army quickly designed a counter strategy, leading to one of the major battles of the war (Fricke, 1954). The Czar's army lost 250,000 men as a result of the Germans use of Radio Intelligence. This is the first recorded victory for Radio Intelligence in warfare (Kahn, 1983, p. 101). Because so very much has been written on the role of cryptography in World War Two, the subject will not be further addressed here. Instead, this paper will discuss the role of Traffic Analysis, Radio Direction Finding and Radio Fingerprinting.

RADIO DIRECTION FINDING

Radio Direction Finding (RDF) is the technique of locating a radio transmitter by measuring the intensity of the received signal in various directions. A transmitted signal is analogous to a pebble dropped into a pond of still water: Ripples—the signal—radiate outwards from the source. At the receiving station an antenna is rotated-electrically or mechanically—until the signal strength (or, more commonly, the null or lack of a signal) is indicated. The direction of the source of the signal—the transmitter—may now be deduced.

The principles of RDF have been understood since the dawn of wireless. A signal may be plotted and located on a map thus determining the location of the transmitter. In Radio Intelligence, this is useful in determining the enemy's Order Of Battle. Other intelligence uses are the location of clandestine transmitters, for rescue operations and to determine one's own position.

RDF was well established by the time of the First World War during which the SE1012E was used. Kahn (1968, p. 270) reports that the French Army alone made more than 17,000 RDF fixes on the Western Front. By 1919 the Adcock system had been perfected. In the Adcock method of direction finding, two co-located perpendicular loop

antennas are used and the arctangent of the ratio of the signals detected by each antenna can be used to determine the bearing to the transmitting station. Sterling (1990) discusses the especially heavy use of the Adcock system in use by the Radio Intelligence Bureau of the Federal Communications Commission to locate and capture German and Japanese spies. The location of a transmitter by the use of RDF requires two or more stations with RDF capability, various maps and rapid communications between these searching stations. Other equipment, although not absolutely necessary, would expedite the RDF process, and would include panoramic receivers, mobile DF vans and even aircraft.

Fig. 3. German body-worn direction finding receiver.

During World War Two, the Wehrmacht used panoramic receivers capable of receiving signals from 10 KCS to 30 MCS. This includes the Very-Low Frequency, the Low and Medium frequencies and all of the High frequency spectrum (Lorain 1983. p. 37). The search operators were assigned a range of frequencies to monitor and a list of stations authorized to transmit within that range, along with their call-signs and assigned frequency. An illegal transmission would generate a "blip" on the cathode-ray tube of the searching panoramic receiver indicating the existence of an unauthorized transmission and its frequency.

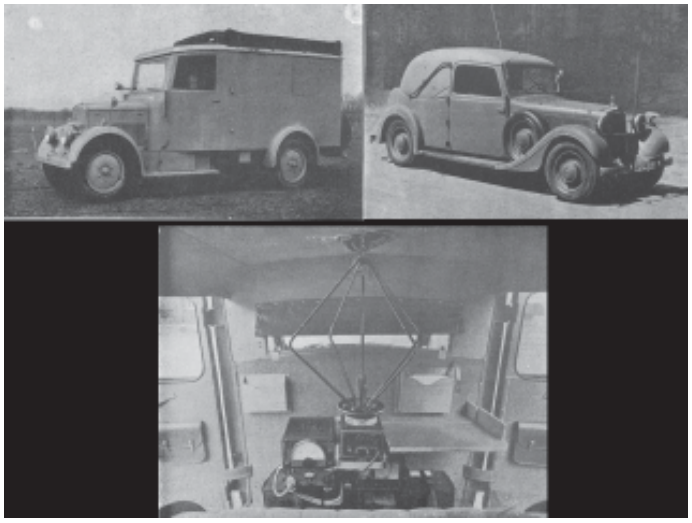

Fig. 2. German mobile direction finding equipment.

The search operator would quickly tune to the frequency

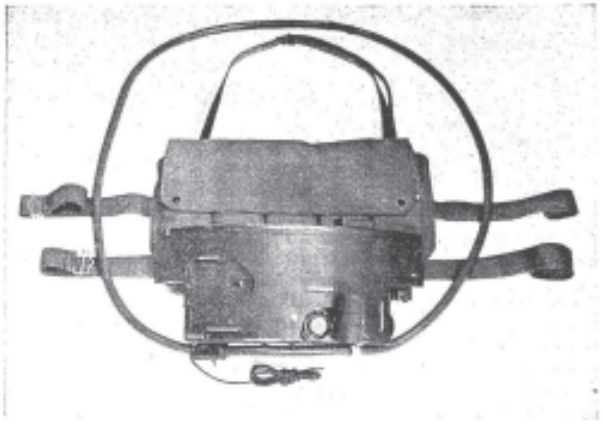

Abbildung 56
Ansicht eines kompletten Gürtelgerätes.

Fig. 4. German body-worn direction finding equipment.

of the unknown transmitter and seek to determine if it was a friendly radio merely off frequency or an illegal set. Meanwhile, the process of taking a compass bearing would beunderway by rotating a loop antenna to establish the bearing of a null. Once the azimuth to the illegal station was determined, a line would be drawn on a map.

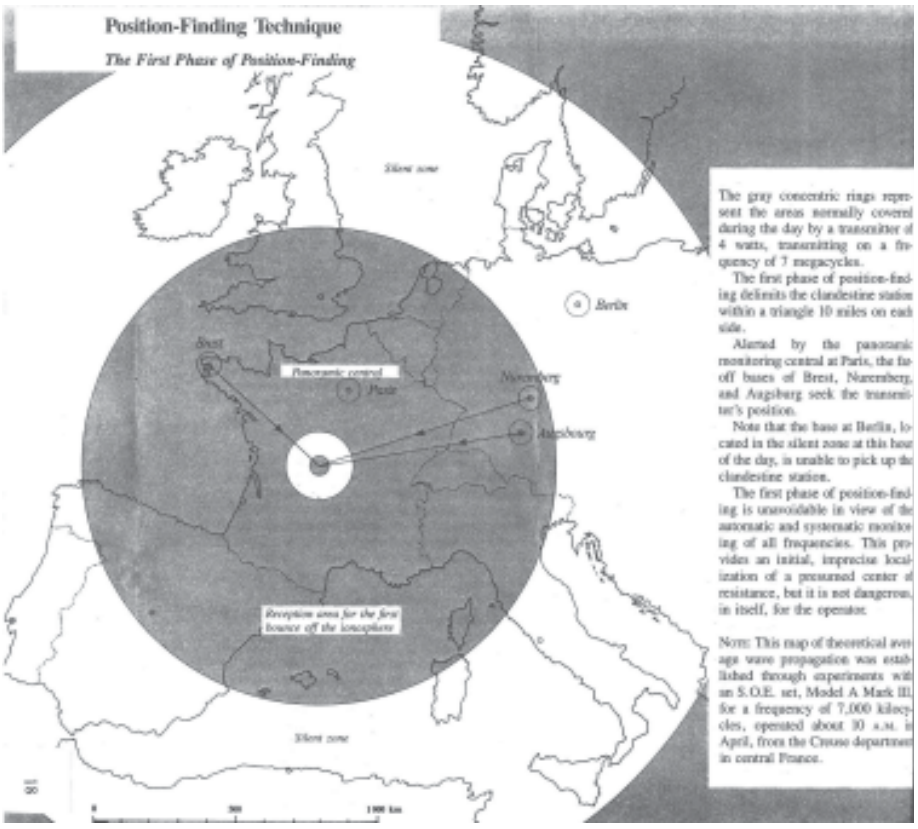
Position-Finding Technique
The First Phase of Position-Finding
Silent zone
Berlin
Brest
Paris
Nuremberg
Augsburg
Silent zone
The gray concentric rings represent the areas normally covered during the day by a transmitter of 4 watts, transmitting on a frequency of 7 megacycles.
The first phase of position-finding delimits the clandestine station within a triangle 10 miles on each side.
Alerted by the panoramic monitoring central at Paris, the far-off bases of Brest, Nuremberg, and Augsburg seek the transmitter's position.
Note that the base at Berlin, located in the silent zone at this hour of the day, is unable to pick up the clandestine station.
The first phase of position-finding is unavoidable in view of the automatic and systematic monitoring of all frequencies. This provides an initial, imprecise localization of a presumed center of resistance, but it is not dangerous, in itself, for the operator.
Note: This map of theoretical average wave propagation was established through experiments with an S.O.E. set, Model A Mark III, for a frequency of 7,000 kilocycles, operated about 10 A.M. in April, from the Creuse department in central France.

Fig. 5. Illustration of the triangulation process (a).

The offending transmitter would be somewhere near or along that line. Now, the frequency in question would be transmitted to other RDF stations so they could receive the same enemy transmissions and so that bearings from these stations could also be taken. The various bearings would then be plotted on a central map. The intersection of the bearings would be close to the location of the illegal transmitter. This process is known as triangulation (see Figures 5 to 8).

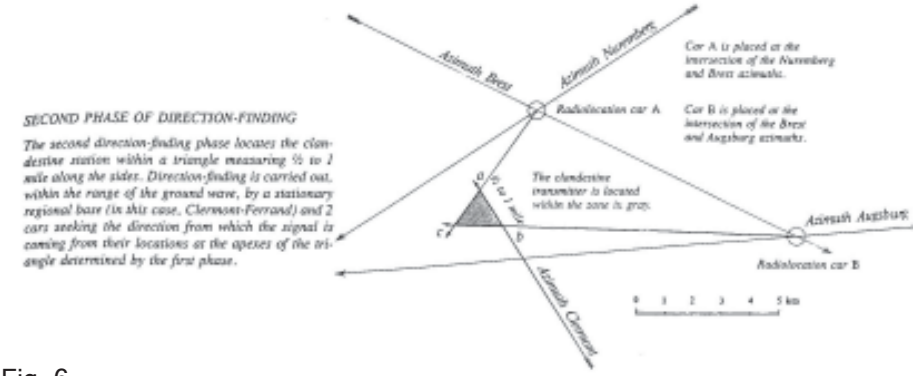
SECOND PHASE OF DIRECTION-FINDING
The second direction-finding phase locates the clandestine station within a triangle measuring ½ to 1 mile along the sides. Direction-finding is carried out, within the range of the ground wave, by a stationary regional base (in this case, Clermont-Ferrand) and 2 cars seeking the direction from which the signal is coming from their locations at the apexes of the triangle determined by the first phase.
Azimuth Brest
Azimuth Nuremberg
Car A is placed at the intersection of the Nuremberg and Brest azimuths.
Radiolocation car A
Car B is placed at the intersection of the Brest and Augsburg azimuths.
The clandestine transmitter is located within the zone in gray.
½ to 1 mile
Azimuth Augsburg
Radiolocation car B
Azimuth Clermont
0 1 2 3 4 5 km

Fig. 6.

Radiolocation car A
0 100 200 300 400 500 m
Approximately ½ to 1 mile
THIRD PHASE OF DIRECTION-FINDING
This third phase locates the clandestine station within a radius of approximately 200 yards. Direction-finding is carried out by A, B, and C vehicles at the intersecting points of the triangle defined by the second position-finding phase.
Note: The operator is not yet in immediate danger, but he should move and never return to the same place.
Radiolocation car B
Radiolocation truck C

Fig. 7.

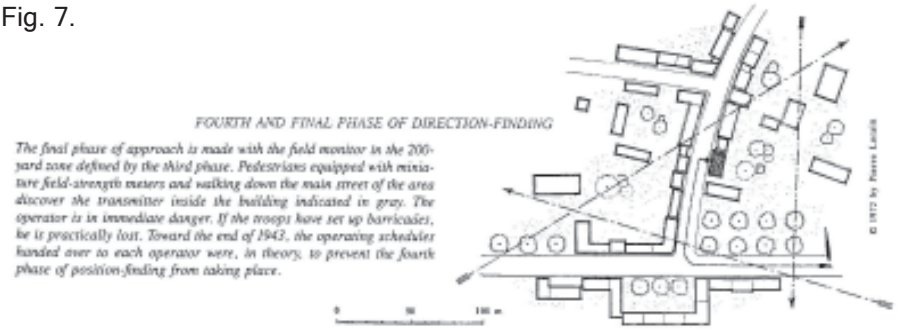
FOURTH AND FINAL PHASE OF DIRECTION-FINDING
The final phase of approach is made with the field monitor in the 200-yard zone defined by the third phase. Pedestrians equipped with miniature field-strength meters and walking down the main street of the area discover the transmitter inside the building indicated in gray. The operator is in immediate danger. If the troops have set up barricades, he is practically lost. Toward the end of 1943, the operating schedules handed over to each operator were, in theory, to prevent the fourth phase of position-finding from taking place.
0 50 100 m

Fig. 8.

As can be seen, the notion of one fix being sufficient to locate a transmitter is a fiction. A single fix gives only the direction to the location but no information about the distance to the location. Thus, it can only provide an approximation of the location. Successive bearings, each closer to the target, are required to narrow down the geographical location of the target transmitter. In French cities, the Germans having narrowed the location of the illegal transmitter to a few city blocks, would systematically turn off the AC power a block at a time. When transmissions abruptly stopped at the moment a block's power was cut, the block housing the transmitter was ascertained.

In theory, RDF seems to be a simple matter but in actual practice several factors could arise to complicate or preclude a successful fix. One of these problems is that the illegal station would not stay on the air long enough for a fix to be taken. Indeed, clandestine operators of both sides were taught to keep their transmissions short, to change frequency often and to never transmit from the same location twice: all to preclude falling victim to RDF. Other problems in obtaining an accurate fix are fading of the signal, false reading of signals bounced off buildings, mountains, etc., and false fixes due to the transmitter being remotely controlled (TM 11-476. p. 140) . Additional factors which may result in errors in DF readings include electrical storms, grounding differences in the various receiving stations, the weather's effect on the propagation of the transmitted signal, the height of the ionosphere (and thus the skip zones) and, of course, the skill and experience of the DF operator. A fix of plus or minus three degrees was considered "good" (Kahn 1991, p.145). At a distance of a mere 100 miles this resulted in a circle with a radius of three miles in which the target transmitter may be located.

It is clear that RDF was somewhat an art and somewhat a science, requiring a high degree of skill and judgment on the part of the officers and men who were seeking to locate the target transmitter. These, together with a series of fixes, would progressively narrow the geographical location of the transmitter in question. There are literally thousands of stories of the use of RDF by all sides in the Second World War. This is understandable when one considers that RDF was a practice well established by 1939. The technology was widely known and widely dispersed. Before the war, RDF was used by the civilian, military, air and maritime services. Ground stations, civilian, civil service and military made routine use of this technology: RDF was a common practice, fairly well understood and widely used by all advanced nations. As a component of Radio Intelligence, RDF had a long history by the outbreak of the Second World War. Kahn (1968, p. 270) tells of the French Army having made

thousands of RDF fixes on the Western front in 1917 alone. The British Royal Navy had a sophisticated system of RDF. Indeed, all of the warring powers used RDF to a remarkable degree (O'Toole, 1991, p. 394).

Direction Finding Nets. The years between the wars saw extensive research and development in RDF, leading to the establishment of chains of RDF stations by the United States and Great Britain together with the development of new techniques to aid the practice of RDF. These were widely used in the Radio Intelligence War. In anticipation of the war, which anyone could see coming, the U.S. Navy had, by 1937, established the Mid-Pacific Strategic Direction Finder net. This chain of RDF listening stations had posts at Cavite, Guam, Samoa, Midway, Hawaii and Dutch Harbor in Alaska (Kahn, 1968, p.8). Later, OP-20-G had a series of RDF stations along the U.S. East coast and the Caribbean.

About this time, the British established a similar series of RDF stations, known as high-Frequency Direction Finding or, more commonly, "Huff-Duff." These stations were intended to aid in the location of German submarines and other naval vessels (Polmar, 1997, p. 260). The Canadians then developed a method of instantly and automatically determining and recording the bearing of the target transmitter (Polmar, ibid.). These stations and their improved techniques were so effective that even a burst transmission would be picked up, recorded and a fix obtained (O'Toole, 1991. p. 394). There exists a well-documented case in which a German submarine surfaced and sent a short burst transmission to its home station. The Allies—in seconds—obtained over thirty fixes on the submarine. Indeed, Kahn (1968, p. 270) reports that the Allies RDF was so highly effective that the only way to avoid being fixed by RDF was to practice total radio silence.

Fig. 9. An American spy burst encoder for sending rapid bursts of secret messages on a transmitter.

On this side of the Atlantic, the Radio Intelligence Division (RID) of the FCC was engaged in tracking German espionage stations before the United States entered the war. Much of this work concerned illegal transmitters in South America, especially Chile, Brazil and Argentina. Sterling (1990, p. 97) describes the RID's effort to locate a German espionage station in Chile in March of 1940. This station transmitted to Germany using the call sign of PYL. Obtaining a RDF fix on this station was very difficult

because the station continually changed location. After weeks of effort, the station's location was narrowed to a ten-mile radius centered on Valparaiso, Chile. It was noticed that every second week the transmissions were made from a certain house located at Avenida Alemana 5508, Cuso Alegre. Routine police work resulted in the capture of the station and everyone associated with the station except the person who actually operated the transmitter. His code name was "Pedro." Pedro escaped and reappeared on the air about a year later. RDF fixes located another German spy transmitter using the call sign PQZ. RID monitors recognized Pedro's "fist." He was eventually captured thanks largely to the RDF fixes provided by the RID. Pedro was a graduate of the German spy school located in Hamburg, Germany. The Pedro episode was briefly mentioned in Moonraker, (Fleming, 1955, p.13), one of the early James Bond novels, authored by the late Ian Fleming.

The use of RDF by the Germans to locate and silence radio transmitters operated by agents of the SOE, OSS, the French Resistance, et al. has been mentioned above. Lorain (1983, p. 172) discusses the capture rate and the cause of capture of some of these agents by German RDF. The great majority of captures were due to three breeches of security by the radio operators. The largest single error was transmitting too long, thus giving the enemy RDF operators time enough to get accurate fixes on the transmitter. The second frequent breach was not changing location often enough. Either of these would seriously endanger the operator, but the two combined would almost certainly result in doom. The last major error was in transmitting from a location near German RDF stations, thus making the job so much easier for the enemy.

In the Pacific, both the Americans and the Japanese used RDF extensively. The American use of this technology in the Pacific was pioneered in the 1920s and 1930s. Admiral Zacharias gives an excellent history of the use of Radio Intelligence against the Japanese from the 1920's to the end of the war (Zacharias, 1946).

Following the end of the First World War, a U.S. Marine staff officer, Major Pete Ellis, wrote an intelligence report entitled "Advanced Base Operations in Micronesia" in which he predicted the sneak attack by the Japanese and the coming Pacific war. This paper, together with the history of the Japanese-Russo War of 1905, the Japanese war in China, the deteriorating political developments and pressing economic needs clearly indicated that a future war between the United States and Japan was inevitable. In anticipation of this coming war, the U.S. Navy had established FRUPAC, the Fleet Radio Unit, Pacific Fleet. By 1941, the member stations of this unit were heavily engaged in Radio Intelligence and the use of RDF. One of these sta-

tions, code-named Hypo, actually tracked all Japanese capital ships of the Imperial Navy from their home islands across the Pacific until the third week of November 1941, when these ships suddenly invoked radio silence. As discussed in Traffic Analysis, this is a highly accurate predictor of a coming action—in this case, an attack by the naval power of Japan upon the United States fleet at Pearl Harbor.

Thus, RDF was used by all the warring powers in all theaters in the Second

World War, both for routine use such as allowing a ship or aircraft to locate its position, as well as for extensive use in Radio Intelligence. As the thousands of reported cases indicate, its importance cannot be overstated.

TRAFFIC ANALYSIS

Traffic Analysis (hereafter simply TA) is perhaps second only to crypto-analysis as a source of information derived from the enemy's signals. Crypto concerns reading the information contained within the intercepted message. Kahn (1968) has written extensively on the practice and results of crypto. TA, on the other hand, is concerned with everything transmitted except the contents. Thus, if the message cannot be read useful information can still be derived from the externals of the message (Bamford 1983, p. 127).

U. S. Technical manual TM 32-250 lists six standard elements of military radio traffic. They are:

1. The call-up
2. Order of transmissions
3. The transmission of traffic
4. The acknowledgement or receipt of the traffic
5. Corrections and service
6. Signing off

Other message externals to be analyzed are: (Budiansky 2000, p. 124)

7. The transmission frequency
8. The circuit used
9. Time of transmission
10. The volume of traffic
11. Length of the message
12. Mode of transmission (CW, AM, FM, RTTY, etc.)
13. The number of addressees
14. Where did the message originate. (Use of Direction Finding)
15. Who are the addressees
16. Priority of the transmission
17. Grade of the cipher system

Not all of these elements will be found in all messages but an analysis of those present, augmented by radio direction finding and radio fingerprinting, will, over time, reveal or indicate an astonishing amount of material about the enemy's order-of-battle, intentions, the location of the transmitting stations (and thus his headquar-

ters), and other information—all without actually reading the message.

The order-of-battle (OOB) is the identity and disposition of the enemy's forces. If a military commander knows he is facing a Panzer division rather than an infantry regiment and knows the disposition of the opposing forces, he is in a position to attack or to defend in an economical, timely and prudent manner. In a static battlefield situation or with ships at sea, Radio Direction Finding (hereafter RDF) can locate the geographical position of the enemy's transmitter. To determine his order-of-battle the analyst must now determine who is communicating with whom.

This is easily done by diligent monitoring of the transmitting frequencies and logging of call signs. Thereafter, a graph is constructed upon a map showing the plotted location of the monitored stations. An excellent example of the Wehrmacht's charting of Russian radio nets is found in David Kahn's *Hitler's Spies* (1978, p. 202). The British found that using colored pencils was the easiest way to chart the various networks they monitored (Drea 1992, p. 124) Today, computers capture, record and analyze traffic using these same principles. Each station will also have its call sign listed on the map. Kahn (1978, p. 202) has published a Wehrmacht map produced on the Eastern Front, which depicts a Russian Army net. It can be clearly be seen which stations communicated with which, their call signs, frequency, etc. The British went so far as to have three separate

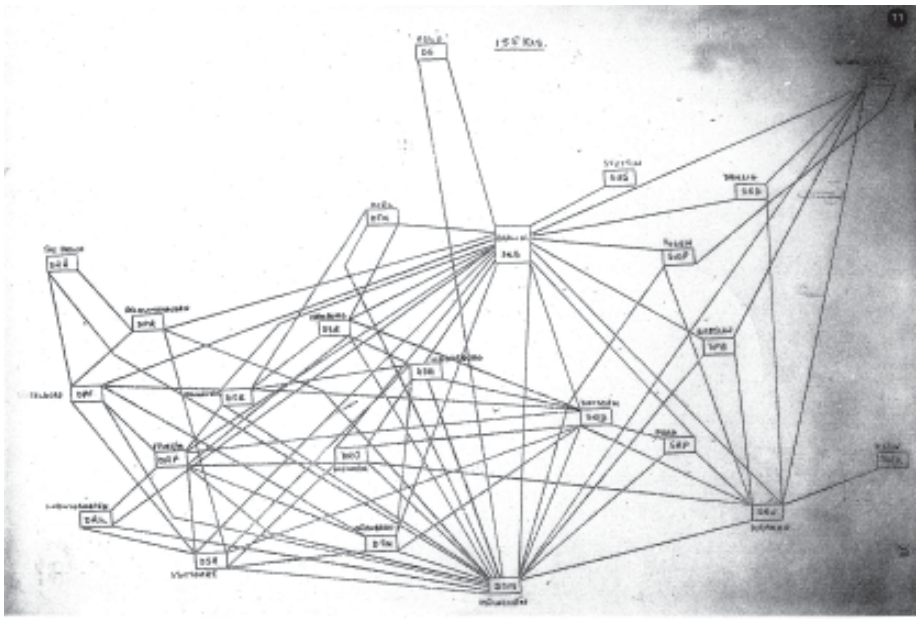

Fig. 10. German military stations.

card indexes, one for calls, another for frequency and still another for different locations (Kahn 1978, p.203). This knowledge is of immense value to the cryptanalyst as it allows him to direct his scarce resources of time and energy to stations—and thus, headquarters—of higher echelon where encryption is much more likely to contain valuable information than would messages originating from a lower level.

Generally speaking, a tactical situation on land will find that the lower echelons (and their transmitting stations) physically closest to the enemy and the higher echelons will be positioned farther back; that is, the physical distance from the opposing forces tends to be proportional to the level of echelon. At sea this is not so apparent but can still be derived.

The analysis of echelon to determine the enemy's order-of-battle is an exercise in deduction. In a given tactical situation, military forces operate in a similar manner. Thus, once the stations are plotted on a map, TA will give great insight to the disposition and identity of the opposing forces in that sector.

Fig. 12. Codebreakers at work.

Fig. 13. Radio intercept receiver setup at Bletchley Park.

Table 1 shows **c**omparisons of some message externals of low and high echelons:

Fig. 11. Bletchley Park

External Characteristic	High Echelon	Low Echelon
Transmits to	Many stations	Few stations
Volume of Traffic	High	Low
Message Length	Long with multiple parts	Brief
Encipherment	Frequently, always	Rarely,simple
Machine Transmission	RTTY, etc.	None
Distance Covered	Long	Short
	HF Skywave	HF Goundwave
Frequency	HF	HF, VHF
Emission	CW, some AM	AM,FM, some CW
Power	High (SCR 399)	Low (SCR 300,654)
Changing Location	Infrequent	Frequent
RDF Location	Rear	Forward

Experience in the Second World War showed a high degree of accuracy in deducing an enemy's order-of-battle, thus giving the opposing commander invaluable information as to the identity and disposition of the enemy he was facing. Once these are known, the commander needs to know the intentions of the enemy commander. In many instances this was provided by TA.

Since the earliest days of Radio Intelligence, TA has provided the analyst with accurate indicators of the enemy's intentions. West (1986, p.165) tells how the German offensive of 1940 was preceded by a sudden increase of radio traffic by the Abwehr to their stations in France, Belgium and Luxemburg. History has shown that a sudden increase in traffic is a highly reliable indicator that an attack is in the making. A sudden increase in traffic followed by a period of radio silence means that the attack is imminent. With RDF and the plot map mentioned above, the commander now knows what is about to happen (an attack), where it is to happen (RDF) and, roughly, when it is to occur and the identity of the enemy forces to be encountered. The examples that follow demonstrate these points.

The Japanese attack on Pearl Harbor followed the classic procedure of military radio: a sudden increase of transmissions, then radio silence. Naval analysts knew something was afoot (Stinnett, 2000). Later, Japan found that a sudden increase of traffic from American transmitters directed from Hawaii to the Pacific South West preceded a move in that direction (Polmar, 1997). In the ground campaigns of the war in the Pacific, the Americans quickly realized that Japanese transmissions on a particular frequency always forecasted a nightly air raid (Kahn 1968, p. 578).

Other message externals may reveal the enemy's inten-

tions. A sudden switch to a high-grade cipher, for example, may signal an outbreak of hostilities (Bamford, 1983, p.127). Unusually long messages or a sudden change of call-signs are indicators of hostile action, as are changing of radio frequencies. An example of this is related by Stinnett (2000, p. 184). As the Japanese fleet sailed from Japan to Pearl Harbor, the transmissions from the home islands to the fleet were changed from 12,330 kilocycles to 16,620 kilocycles to accommodate the increasingly distant fleet. The U.S. Navy monitoring stations quickly realized the significance of this.

Kahn (1978) relates an incident whereby a high volume of traffic preceded a withdrawal of enemy forces. A withdrawal under fire is always a complicated business and sure to require a heavy level of radio traffic. Attacks, troop replacements, and even disciplinary problems may also generate high levels of traffic (Kahn, 1978, p. 203). Other uses of TA are to aid cryptanalysis, assist further interception, to rate the value of the interception and to improve our own communications security.

As mentioned earlier, TA, along with DF, can result in a map upon which is plotted the location of the enemy station. Routings are then drawn upon the map, these depict which radios talk with which other radios. The intercept operator now knows the following facts about his enemy:

1. The location of each station and its plot on a map
2. The echelon of each station
3. To whom each station transmits
4. From which other stations each station receives traffic

The data used to assist cryptanalysis is also used to aid further interception and TA. When units or ships enter a military area of operations, message routing indicators and new call signs will indicate this. Changes of call signs are only effective for a short period of time in disguising the presence of new units to the Order of Battle. This is due to the "fingerprinting" of the enemy's transmitters (See below). Another factor used to identify enemy organizations is the unique "fist' of operators assigned to a particular unit's headquarters. Where the fist goes, so goes the headquarters and thus the unit. An example of this occurred in 1944 when the Wehrmacht intercept service followed the American 82nd Airborne Division from Italy to England shortly before the D-Day landings. Prior interceptions and TA by the Germans caused them to know well the unique "fists" of the American radio operators. When these fists were no longer heard in Italy, the logical conclusion was that a division as competent as the 82nd Airborne must have been relocated to England in preparation for the

D-Day invasion that everyone knew was imminent. The Germans knew full well that an airborne division such as the 82nd would be a spearhead in the invasion force from England. Thus, they listened for the familiar fists in Southwest England and there discovered the missing 82nd. Division. Once the operators were found, the division itself was found. Prior TA and routing maps of radio nets were changed to reflect the new traffic from the "new" division, thus making the job of the German intercept operators much easier and confirming the findings of the "fist tracing".

Stinnett (2000, p.124) tells of the U.S. Navy having maintained an on-going analysis of Japanese naval transmissions since the 1920s. This TA established traffic patterns for various commands and revealed who talked with whom. It also established the normal volume of traffic for particular circuits undervarious operations. When volume dramatically increased in 1941, it was clearly understoodthat a major naval operation was under way by the Japanese.

Rating the Level of Intelligence. This is a valuable by-product of TA. Radio traffic from Division, Army or Corps levels will certainly contain information of more value than that transmitted by the lower echelons. The intercepted traffic may be classified by the echelon of the transmitting and originating headquarters via the use of DF, call signs, radio footprinting, fist recognition and the all-important plot of the enemy's Order of Battle. In war, when time is critical, this gives the analyst a huge advantage as he now can direct his scarce resources, time and energy, to messages whose probability of containing a high level of intelligence is much greater than those having been transmitted by lower levels of command.

Improving One's Own Radio Security. Intercept operators are routinely assigned to monitor stations of their own side. As a traffic cop looks for violations of the speed laws, so does the intercept operator look for violations of radio security, radio procedure, operator error, unauthorized transmissions, etc. In essence, they are the traffic cops of the ether—no pun intended. By doing so they improve friendly communications and make TA by the enemy a more difficult task. The operator's role here is passive; he merely monitors transmissions and reports violations to the proper department for follow-up. An active role is put into motion when the analysts seek to break the radio security of their own forces.

Some of the methods used are:

1. Joining a net to pass on false traffic and generate confusion
2. Using a legitimate call sign to receive traffic but not to relay it on
3. Requesting numerous repeats of lengthy transmissions
4. Asking that encrypted messages be transmitted in clear due to QRN, (atmospheric noise) etc.
5. Attempting to engage other stations in authorized chatter
6. Inducing operators to break radio silence—frequently by transmitting a false SOS or other false emergency traffic.

It can be seen that Traffic Analysis is a complex undertaking but one that can pay enormous dividends of intelligence—all without being able to actually read the contents of the message. TA is only one component of Radio Intelligence. The other players in the game are Cryptanalysis, Radio Direction Finding and Radio Fingerprinting. The latter shall now be examined.

RADIO FINGERPRINTING

Radio Fingerprinting is the technique of identifying a particular operator or transmitter. Although the terminology has yet to be standardized, the identification of an operator is generally referred to as Radio Fingerprinting, while the identification of a particular transmitter is referred to as Radio Footprinting. Radio fingerprinting came into practice with the introduction of landline telegraphy in the 1800s. The ability to recognize the unique touch of a telegraph key, and thus the operator doing the transmitting, became a common practice among all telegraph operators. Commercial, amateur and military operators quickly grew to recognize the distinctive "fist" of the sending operator; a mark as distinctive as his signature or voice.

The ability to recognize a radio operator by his distinctive style of sending was immediately used by the clandestine services to prevent deception as their operator could be determined with certainty—it was thought. Later, this technique would be used to track an enemy operator as he moved about, and hence the ship or military unit he was known to be a member of could be followed. Another cause of deception in secret warfare was the ability of one operator to perfectly duplicate the sending style of a captured enemy radio operator, thus allowing the feeding of false information to the enemy who thought he was listening to his own agent.

The clandestine services, especially the British SOE, sought to use the unique fist of their operators as a security check. These operators, deep into enemy territory, were in great danger of being captured and forced to transmit false information to their home sta-

tions. To ascertain that the sending operator was indeed who he seemed to be, his fist had to be verified. The British technique of verifying an agent's fist was known as "TINA". Before being sent into enemy territory, the radio operator would transmit a test message, which would be recorded and examined on the cathode-ray-tube of an oscilloscope. The spacing between the dots and dashes, the length of each of these, the timing between dots and dashes and the spacing between characters would generate a unique pattern of that individual operator's fist. This display of the sending pattern would be photographed for later reference. An example of this display is included here (Fuller 1975, p. 173, shown as Fig. 14).

This system of authentication was used from 1943 on with considerable success. Each operator was "finger-printed" monthly and resulted in an entirely reliable method of verifying the identity of the transmitting operator. Thus, any change of operators was immediately detected by the home station. One would think the fear and tension of operating a clandestine station behind enemy lines would affect the operator's sending pattern but it did this only to a minor degree, and not enough to nullify TINA. The general pattern of the operator's sending persisted (Lorain 1983, p. 171). Attempts to disguise one's fist do not appear to be successful. Sterling (1990, p. 97) tells of a German espionage operator in South America (the previously mentioned "Pedro" who was silent for over a year. He resumed transmitting to Germany using his left hand to change his fist. He also changed his call-sign. These changes were to no avail and he was quickly identified and caught. This true incident is also briefly mentioned in Moonraker (Fleming 1955, p. 13).

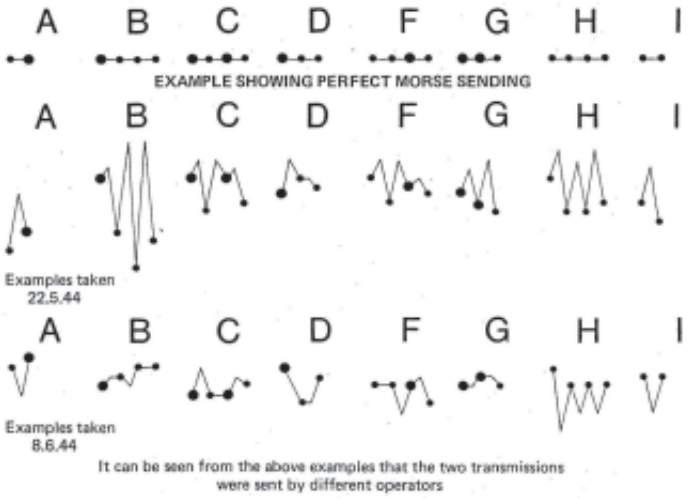
A B C D F G H I
EXAMPLE SHOWING PERFECT MORSE SENDING
A B C D F G H I
Examples taken
22.5.44
A B C D F G H I
Examples taken
8.6.44
It can be seen from the above examples that the two transmissions
were sent by different operators

Fig. 14. Oscilloscope traces from the TINA technique.

There have been numerous instances of ships, aircraft and military units being tracked by the fists of their radio operators and their locations plotted. As previously mentioned, the Germans tracked the American 82nd Airborne Division from Italy to England shortly before D-Day. The Germans were keenly aware that an elite division such as the 82nd Airborne would play a key part in the initial stages of the invasion. Thus, the discovery of this division would be a key indicator of the pending action. The British thought the technique of tracking organizations by the fists of their assigned operators was so valuable that their "Y" Intercept service developed a card index file for every recognizable enemy radio operator (West 1986, p.153). By this method each operator's geographical movements, his different assigned call-signs and his idiosyncrasies would be cataloged for later reference. The enemy will expend considerable time, money and effort to monitor the transmissions of his opposition. Thus developed a fairly common practice in the Second World War of leaving the organization's radio operators behind to transmit dummy traffic while the ship or unit, with new and different operators-traveled to its new designation (Kahn 1978, p. 201).

The transmission of dummy traffic was also used to deceive the enemy into recognizing entire organizations that in reality didn't exist. Perhaps the best known example of this was General George Patton's notational First U.S. Army Group (FUSAG) transmitting fake traffic from East Anglia in the days preceding the D-Day invasion. The purpose of this ruse was to allow the Germans to recognize the known fists of FUSAG's operators and then plot their location using RDF. The Germans then were misled into believing that General Patton's army was a real entity, and was located in East Anglia—across the English Channel from Calais—and therefore the invasion was not imminent. In this instance, the deception was completely successful.

As mentioned earlier, "fists" can and have been imitated. A good example of this is the William Sebold affair of 1940. Sebold was a naturalized American citizen who was blackmailed into working for the Abwehr. At the first opportunity he contacted the American authorities and revealed his orders. As a patriotic American he agreed to serve his adopted country as a double agent. Sebold's German controllers ordered him to establish a radio station and act as the communicator for a ring of approximately thirty German spies operating in the New York City area. The FBI established his station on Long Island. This station transmitted CW on 14 MCS and imitated an amateur radio station working DX on the 20 Meter amateur band. His call was CQDXVW2 and he was seeking contact with AOR in Hamburg. As the U.S. was not yet in the war, its amateur op-

erators were still operating on ham frequencies as before. The FBI would not allow Sebold to actually key the transmitter, so the station was operated by an FBI Special Agent Morris Price who held a Class A amateur radio license. He successfully imitated Sebold's fist during many QSO's with Hamburg over a fifteen month period of time (Sterling 1990, p.82). This affair has been somewhat realistically depicted in the 1945 movie *The House On 92nd Street*.

A similar example of the FBI imitating the fist of a German agent took place in 1943, again on Long Island. A Dutch citizen posing as a refugee was to establish a radio station and communicate to Germany. As did Sebold, the Dutchman, named Koehler, went to the American authorities while still in Madrid. Upon arrival in the U.S. he was met by the FBI who built the station and operated it by successfully imitating Koehler's fist (Breuer, 1989, p. 297). Following the successful imitation of Sebold's fist and the consequent catastrophe to German intelligence, the Germans then began to record the CW sending pattern of its agent-op-

Fig. 15. German spy posing as an Amateur Radio Operator.

erators before dispatching them to the field, much as the British did with their TINA system (Sterling 1990, p. 91).

The British also had success in imitating the fist of captured agents. At the beginning of the war, the Germans sent many spies into Britain by a variety of means. Most carried small wireless sets with which to radio information back to Germany. As the British were fully informed of the arrival of these agents via Ultra intercepts (deciphered Enigma messages), all were captured upon arrival or shortly after their arrival in Britain. The captured German agents were then given a choice: to work for the British and transmit false information to their former masters, or to be executed.

Most, but not all, chose the former. Most of these now-turned agents were allowed to actually key their transmitters but some were imitated by British military or naval signal-men (Masterman 1972, p. viii). The ruse was completely successful; the Germans never caught on. Although most of the captured German operators were allowed to key their own transmitters under close supervision, the need to be able to successfully imitate the fist of these captured agents was always extant. It appeared that the war would be a long one and the possibility of a captured agent refusing to continue to cooperate, becoming seriously ill or dying was always a possibility. For these reasons their fists were studied and a standby operator was available (Masterman 1972, p. xv).

The ease of imitating an operator's fist caused the SOE and the OSS much concern. No longer could a signal with the correct keying pattern-as verified by TINA- be known as genuine; anyone could be at the key, or the operator could be operating under duress. The solution was the insertion of one or more security checks. The security checks took two forms: early in the war, when both transmission and reception occurred at the same time, the home station would ask a question such as "What is your mothers name?" If all were well, the correct answer would be something totally illogical such as "Tonight, at six o'clock". Later, when the radio security services adopted the naval "Fox" procedures whereby transmissions from enemy locations were carried out during the day and reception was done at night. The security check then consisted of a deliberate mistake such as every twelfth letter sent as a Q, or the sixth word deliberately misspelled. (Giskes 1953, p. 184).

The North Pole operation was one of the great examples of radio warfare in the Second World War. Lt. Lauwers was a Dutch officer serving as a radio operator for the SOE in The Netherlands. He parachuted into Holland and was captured by the Abwehr during the North Pole operation. He gives a very clear discussion of his security checks and the attempt of the Abwehr to discover

them so as to trick the SOE into accepting a German operator as Lt. Lauwers. The North Pole operation is a classic in the history of Radio Intelligence and is "must' reading for any serious student of the subject (Giskes 1953, p. 175).

RADIO FOOTPRINTING

Of the various techniques of Radio Intelligence in the Second World War the most fascinating and least known is the method of identifying a particular transmitter by displaying the received signal on a cathode ray tube and recording it. As every transmitter generates its own unique and unchanging pattern, the pattern can be codified and catalogued for future reference and identification. This is known as Radio Footprinting. This is similar to using a person's fingerprints for positive identification. A modern day parallel is the use of voiceprints to identify the speaker.

Once a transmitter's signal is displayed on the cathode ray tube and photographed, it is instantly recognizable in the future. The location, operator's fist, the call sign, the frequency and the mode of emission may all change but the transmitter and the military organization or ship it is known to belong to are known with certainty.

This technique was known as early as the 1920s and invented by Professor Alistair Hardy. It was introduced into the British Royal Navy in 1941 (Smith, 2000, p. 84). In World War Two it was used extensively by the United States and British Navies to identify and track capital ships of the enemy. Surprisingly, there has been little—very little— published on such a useful and valuable tool. This technique is not mentioned at all by Jones (1978) in what has become the standard bible of British Technical Intelligence in World War Two. The technical details of Radio Footprinting at the transmitter are common and known to any radio engineer or ham radio operator. These details are the unintended transmission of spurious emissions, the level of filtering of the input voltage of the power supply, the amplitude of the signal, the percentage of modulation of the signal, the rise and decay times of the signal, and other parameters determined by the design of the transmitter. The secrecy seems to revolve around how these details were used and especially how they were detected at the receiving end.

When keyed, all transmitters will emit spurious signals known as a "chirp." This is inherent in even the best designed radios and cannot be eliminated. All that can be done is to minimize the chirp so that it cannot be detected by ordinary means. In transmitters of the 1939-1945, era the chirp was present but was ignored because it was suppressed below the threshold of normal detection and did not affect communications. When detected by the engineers of Radio Intelligence, however, the chirp was the major component of the transmit-

ted signal allowing identification of the transmitter. A second component of the transmitted signal was the "hum" or ripple originating from the input of alternating current to the power supply. After rectification, this ripple was largely, but not completely, filtered out. As with the "undetectable" spurious emissions, the residual hum was thought to be of no consequence since it did not interfere with communications. It was the second identifying component of the soon-to-be identified and codified enemy signal. Radio Footprinting could determine the design of the transmitter, often by determining the number of buffer stages or the lack thereof. The amplitude of the signal and its rise and decay times also made the transmitted signal unique and rendered it susceptible to identification and cataloging.

The receiving, examining and cataloging of the enemy signal is where the genius of Professor Hardy excelled. Elphick (1997, p.154) describes how the signal is displayed on an ordinary cathode ray tube as it is received. This real-time signal is then recorded on a high-speed movie camera using special high speed film. All idiosyncrasies arising from the spurious emissions, hum, etc. are noted and cataloged (Smith 2000, pp.53 and 325). Collectively, they are the unique and unchanging pattern or "footprint" that will positively identify that particular transmitter in the future.

In the Far East, the British built a virtual electronic dictionary of every major Japanese vessel. The stations doing the receiving, recording and identification of the enemy transmitters were those of the High-Frequency Direction Finding (Huff-Duff) service that has been previously discussed (Elphick 1997, p.157.).

The lack of information concerning Radio Fingerprinting would indicate that the secrecy concerning this technique has largely persisted to the present time. There appears to be no evidence of this technique being known or used by the Japanese or the German intelligence services. A modern day note: Radio Footprinting is now used to identify cell phones that have been stolen or used for illegal purposes.

DENYING RADIO INTELLIGENCE TO THE ENEMY

Up to this point, this paper has shown how military and naval organizations monitored the signals of their enemies to harvest radio intelligence in the Second World War. This was done with great success. Now we shall examine the other side of the coin: How does a commander prevent the enemy from obtaining radio intelligence?

The most effective way to prevent the enemy from obtaining radio intelligence is to not generate it in the first place! Avoid the use of radio, especially HF radio. An excellent example of this was practiced in the Wehrmacht's preparation

for the Battle of the Bulge in December 1944. By this stage of the war, the Germans had a fine appreciation of the Allies' ability to analyze radio intelligence. Thus, they forbade any use of radio in the preparations for the battle. All communications were carried out by messengers, wire or mail. The American and British forces had no indications of an upcoming action and were caught completely unaware. The Wehrmacht's clever surprise was complete and absolute. There are numerous examples everywhere of the practice of radio silence to deny radio intelligence to the enemy. There are obvious problems with the use of radio silence, however.

The most obvious problem is that there are often times when communications are necessary. Naval vessels often use signal lamps or semaphore flags if the distance is not too great. Aircraft use previously agreed maneuvers (dipping wings, lowering landing gear, etc.) to communicate. All military aircraft were equipped with Morse telegraph keys to allow them to flash Morse Code to other aircraft using their aircraft lights. These methods work up to a point but are often hampered by distance, weather, nighttime, etc. Another problem with radio silence is that the very use of — the dropping off of normal chatter—is an indicator that something is brewing. Thus there are situations in which the use of radio cannot and should not be avoided.

Obtaining intelligence from the enemy's wireless cannot happen if the enemy engages in radio silence. When the enemy engages in radio silence, means must be found to persuade him to transmit. One method of doing so is to imitate another enemy station seeking to establish contact with the silent enemy station. The author knows of a cold war case where a Russian station was tricked into sending a five hundred-group message to an imitator. Another tried and true method to force enemy transmissions is to attack or appear to invade the enemy's air space, waters or land. The resulting burst of transmissions frequently results in the harvesting of radio intelligence. The ferret flights, the last mission of the U.S.S. Pueblo, and the Gulf of Tonkin incident are recent examples.

During World War Two, the allies used VHF radio with great success in the Pacific. The very nature of the propagation of VHF limits it to line-of-sight transmissions. The U.S. Navy used the TBS, MBF and other radios in the 60 to 80 MHz frequency range to talk between ships at sea. The chance of intercept was nil. This precluded the possibility of Radio Direction Finding, Traffic Analysis, Radio Footprinting or Radio Fingerprinting by the Japanese.

In Europe, the British SOE inserted agents into enemy territory equipped with radios contained in suitcases. The most common was the 3 Mark II (B2) transceiver which weighed 32 pounds. This set

operated from 3 to 16 MCS. Later, agents were supplied with the smaller Mark III transceiver that weighed about nine pounds and operated from 3 to 9 MCS (Lorain 1983, p .54-57).

Fig. 16. Spy suitcase radio.

Fig. 17. Spy suitcase radio.

These radios were the best available at the time but burdened the operator with many inherent problems. Some of these were:

- o The sets were large and heavy.
- o They consumed enormous amounts of power.
- o They were difficult to camouflage.
- o They operated on the High Frequencies.
- o They required large antenna systems.

The last two above-mentioned problems were especially serious. In urban areas since it was difficult and dangerous to erect the large antennas required for HF. The greater and much more dangerous problem was that the use of HF left the agent susceptible to Radio Direction Finding at which the Germans excelled. This all too often led to the agent's capture or death.

The British were well aware of these problems and worked overtime to solve them. By 1943 the SOE had fielded the near-legendary S-Phone (Type 13, Mark IV). This was a miniature, man-carried UHF transceiver operating from batteries. The operator wore a web harness that contained the numerous batteries and to which were attached the small antenna. The frequency and antenna of this set resulted in a cone-shaped signal from the set upward into the sky. Any ground station more than a mile distant could not detect the signal. This virtually precluded detection, capture or the gathering of any radio intelligence by the Wehrmacht. The S-Phone was a very successful radio that completely overcame the major deficiencies of the earlier HF sets.

The American OSS issued its agents with the SSTR-1 HF radio system. This was similar in most respects with the British HF sets described earlier. It also had the same problems of requiring a large antenna system and—being since it was HF— being highly vulner-

Fig. 18. The British S-Phone.

able to Radio Direction Finding. The American solution to this problem was a state-of-the-art VHF radio called the Joan-Eleanor. This was a very successful set operating at 260 MCS. Unfortunately, it was introduced in the latter part of the war. This set was much smaller xxthenxx than the British S-Phone and was hand held. The set weighed four pounds and did not require the bulky web harness of the S-Phone. The Joan-Eleanor was officially designated SSTR-6 and cost the US Government $1,913 each (Cain 1993, p. 61). In appearance it was very similar to modern hand-held amateur radio 2-meter transceivers (Fig. 19).

This set was introduced into the field in 1944, the year following the introduction of the S-Phone.

Like the S-Phone, this set transmitted a cone shaped signal straight up to a friendly aircraft. This aircraft was frequently a British Mosquito, orbiting at 30,000 feet, completely out of sight and sound of the OSS operator or any Gestapo agents in the vicinity. The Germans were aware that low flying and especially circling aircraft were often dropping agents, resupplying resistance forces or engaging in other clandestine work. Thus these aircraft were a prime interest to the Wehrmacht and Gestapo. This danger did not occur with the use of Joan-Eleanor as very high flying aircraft could not be seen or heard from the earth.

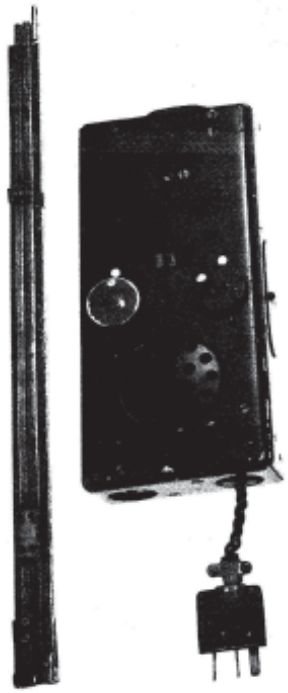

Fig. 19. The Joan-Eleanor.

At times the use of high frequency radio is unavoidable. In these times, the commander must assume that the enemy is aggressively monitoring his signals to glean all the radio intelligence available. History has shown this to almost always be true. When the use of HF is a last resort and the interception and analysis of his signals is almost a certainty, there are steps a commander can take to minimize the information available to the enemy.

The following steps have been used to minimize the possibility of being detected by enemy RDF:

· Use the lowest possible power to communicate.
· Use highly directional antennas.
· Use ground wave.
· Control the transmitter by remote control.
· Change QTH (Location) frequently, if possible.
· In urban areas, use battery power, not the AC mains.

Traffic Analysis. To minimize the possibility of the enemy using traffic analysis, consider the following:

o Change call signs frequently.
o Change frequencies as often as possible.
o Transmit to imaginary stations.
o Continuously transmit encrypted traffic to tie up the enemy's resources.
oBury authentic traffic in phantom nets.

Radio Fingerprinting. To minimize the possibility of the enemy using radio fingerprinting: is:

Use machine-generated traffic. Humans are identifiable.

Radio Footprinting. To minimize the possibility of the enemy using radio footprinting:

Use a variety of different transmitters**.**

Other steps.
Use short burst transmissions.
Encrypt all traffic.
Practice self-policing.

An excellent example of foresight in planning an action to compel the enemy to transmit occurred in August 1914. Prior to this, the Germans had powerful wireless transmitters at Nauen, near Berlin. The Germans also had several undersea cables for purposes of se-

cure communications to France, Spain, North Africa and two cables to the United States. The British anticipated the Germans use of radio silence once the war started in order to deny the British, French and Russians the possibilities of obtaining radio intelligence. In 1912, fully two years before the outbreak of the war, the British navy had a special ship— the Telconia— assigned to retrieve and cut the German under-sea cables on the first day of the war, thus forcing the Germans to use wireless. This allowed the Allies the ability to monitor the Germans wireless traffic and glean intelligence from it; — a feat that would not have been possible if the Germans had the use of their cables. Thus the saga of Room 40 began (Tuchman, 1958, p. 11). Room 40 was where the British gathered a team of codebreakers and radio intelligence experts to determine the meaning and importance of German communications. An excellent in-depth study of Radio Intelligence in World War I and the subsequent years to 1939 has been completed by Lee (2002).

DECEIVING THE ENEMY BY USING RADIO INTELLIGENCE

Radio Intelligence is a two-edged sword: a military commander—with improper security and a lack of discipline—may allow the enemy to reap enormous amounts of data from his transmissions. This has been the crux of this paper to this point. The other side of Radio Intelligence is to use it as an offensive weapon to deceive an enemy who is surely listening. If the unprofessional and technically backward army of the Czar used Radio Intelligence in the First World War, then it is a certainty that modern enemies, no matter how unsophisticated, have and will use Radio Intelligence to seek information. Thus, a commander has the opportunity to mislead his enemy by sending him false information—he knows his enemy is listening. A commander may use Radio Intelligence to confuse, misdirect and lull the enemy. A significant side benefit is the huge expenditures of time, money and manpower by the enemy as a result of this deception.

The enemy may be confused by the transmission of false facts, either sent in the clear or in a code. An example of the former occurred in the Pacific where a U.S. Marine unit had advanced and taken a Japanese position. The Marines immediately established a perimeter defense awaiting a counter-attack. The next step was to take roll to see who was missing, wounded and how much ammunition was available. The Company Commander found himself in a very advantageous position: His position was easily defendable with excellent fields of fire, he had few casualties-mostly walking wounded who were still able to fight, no dead and his Marines had plenty of ammunition. The Captain then sought to lure the Japanese into an attack in

which the Marines would almost certainly prevail. He instructed his men to conserve ammunition. There would be only infrequent single shots and absolutely no automatic fire from the Browning Automatic Rifles or from the light machine guns. The Captain then engaged in the deceptive use of Radio Intelligence by sending high-priority messages back to Battalion Headquarters asking for an immediate and urgent resupply of ammunition. These messages contained a touch of panic and were sent in the clear. The Japanese, who were very good at radio interception, acted on this false information and attacked the Marine position. The Japanese attacking force was largely wiped out.

The war in the Pacific saw other uses of Radio Intelligence to deceive the enemy. Perhaps the best-known example is the U.S. Navy's build-up preceding the battle of Midway. In the summer of 1942, the Japanese had conquered vast areas of the Pacific Ocean and were about to expand their holdings. Having broken the Japanese codes, U.S. Naval Intelligence knew an attack was imminent. The enemy radio traffic referred to the various locations by a two letter designation; the target of the attack was designated AF. Although the U.S. Navy was reading the Japanese radio traffic they still didn't know where the attack would occur. Hawaii seemed a likely target, with Midway nearly as likely. There were still other possibilities. Lt. Commander Joseph Rochefort, commander of the Fleet Radio Unit based in Hawaii, felt strongly that Midway Island was the intended target. To ascertain that the Japanese designator AF referred to Midway, Rochefort ordered Midway to send a message in clear stating that the island was short of fresh water. In a few days, the intercept operators of the Fleet Radio Unit had read a Japanese message that stated that AF was short of water. Now the U.S. Navy knew for certain that the attack was to be directed at Midway Island.

Knowing the time and place of the attack, the Navy soundly defeated Japanese Admiral Yamamoto's forces. The battle of Midway is considered to be the turning point in the Pacific war and victory was made possible by Radio Intelligence. Radio Intelligence was used defensively in the breaking and reading of the Japanese codes, and used offensively in planting false information for the enemy (Kahn, 1968, p. 569). The enemy may also be confused by false information transmitted on authentic nets, or by the establishment of false military organizations appearing to be real by the creation of various radio nets passing traffic amongst the non-existent formations and echelons of the phantom organization.

Perhaps the best-known example of this was the creation of an entire army group ostensibly under the command of General Patton prior to the D-Day landings. The Germans had a deep professional respect for

General Patton and assumed he would certainly lead the D-Day attack. To deceive the German High Command into thinking that the Normandy landings were a diversion from the real landings. A fictional army group was created and "based' in Anglia, in southwest England. Numerous radio nets were established to allow the German Y intercept service to ascertain that General Patton and his entire army group were still in England. Thus the Normandy landings had to be only a diversion. This deception was totally successful (Brown 1975, p. 515).

An excellent example of misdirection by radio deception was the British Double Cross System. As has been discussed above, all German agents infiltrated into Britain were captured and given a choice; work for Allied intelligence or be shot. Most chose the former. Under close supervision they established radio contact with their former masters and passed on information designed to confuse and misdirect the Germans. As the agents had to be resupplied with funds, the money was an additional benefit. A greater benefit came from reading the questions the Abwehr sent their agents. By studying the questions, British Intelligence knew what areas the Germans were most interested in and thus, could deduce future moves by the enemy.

One of the most successful agents in the British Double Cross system was a Spaniard known as Garbo. Garbo was totally successful in deceiving his German masters. In 1941 he began working alone and created an imaginary team of agents. As such he sold totally fabricated information to Germany. By 1942 he was in the employ of the British who carefully coached and trained him to become a fully trusted and valuable agent of the enemy. So successful was Garbo that on the eve of the Normandy landings he sent an urgent message stating that the Normandy landings were only a diversion to draw attention away from the real landings that would be at Calais. This message was on Hitler's desk within 24 hours. Hitler believed and acted upon it (Brown 1975, p. 754-758)

Radio deception can cause the enemy to waste large sums of money, time and effort while yielding highly important information to the deceiver. Perhaps the best known and documented example of this is Operation North Pole that took place in Holland starting in late 1941. This was the capture and playback of an entire British SOE (Special Operations Executive) clandestine radio network by the Abwehr. This operation was a near-perfect success for the Germans and an extremely expensive disaster in trained agents, money and material for the British. David Kahn has stated that Operation North Pole was the "worst Allied defeat in the espionage war" (Kahn 1968, p. 538). By late 1941, the British SOE was dropping radio operators and their equipment into Holland to establish and operate clandestine

radio links with London. Very early in the mission the Abwehr captured one of the first of the parachuted radio operators, Hubertus Lauwers. He was a Dutch citizen who had volunteered to return to his home country as a radio operator for SOE. The British were well aware that the probability of Lauwer's capture or death by the Abwehr was very high. SOE also knew that if the operator were captured alive the Germans would attempt to "turn" the operator so as to send messages written by the Germans to London. The SOE, believing the transmissions to be the voice of the Dutch underground, would respond by parachuting whatever supplies were requested.

The Germans routinely used torture and the threat of death to convince the captured radio operators to transmit back to SOE London as though all was normal. Thus, SOE spent much effort to train Lauwers and other operators on how to conduct themselves if captured. In order to stay alive, the agents were told to appear to cooperate with their German masters and to send whatever messages the Abwehr directed, thus preventing torture and death. The absence of the operator's security check in his message would tell London that the messages were being transmitted under duress and should be treated accordingly. In theory, the inclusion or omission of the Security Check would work well. The unfortunate radio operator would be kept alive and free of torture. Messages sent to London would be known to be false and much could be deduced from them. Given the realities of the situation, this was an acceptable solution—in theory.

Lauwer's security check was a deliberate mistake in every sixteenth letter. If the message was genuine, the mistake was made as instructed by SOE in the agent's training. If, however, the agent had been captured he was not to make the deliberate mistake. This absence of the security check would tell London SOE that the agent had been captured and was transmitting under duress. London would respond as if they believed the message, thus keeping their agent alive and harvesting information from messages now known to be false. Lauwers did as he was trained to do. He sent messages to London that had been written by his German captors but with the absence of his security check. At SOE London, however, something went horribly wrong. For reasons that have never been fully explained, SOE accepted and acted on these and other messages of this circuit for nearly two years! The absence of the security check should have been noticed at once but it appears that this was not the case. Some of the reasons later put forth for not acting on the lack of the security code were poorly trained operators in the sending of Morse code, weak signals received in London due to weak transmitters, poor antennas, QRM and QRN (interference from other stations and from atmospheric

noise). This continuing disaster lasted nearly two years. During this time, the British made 95 parachute deliveries, dropping many trained agents, large quantities of money and equipment into Holland. It all fell directly into the hands of the Abwehr.

As discussed earlier, the offensive use of Radio Intelligence can result in a significant loss of time, money and equipment to the enemy. The Abwehr's skillful use of this technique, combined with the SOE's ineptitude cost the British the following:

- 500,000 Dutch Guilders (equivalent to just under $3,000,000 U.S dollars today)
- 30,000 pounds of explosives
- 3,000 Sten guns
- 5,000 Pistols
- 2,000 hand grenades
- 75 radio transmitters and receivers
- 500,000 rounds of ammunition

The SOE also parachuted 54 agents into Holland. Of these, the Gestapo executed 47. It was the worst Allied defeat of the espionage war (Kahn 1968, p. 538). After the war, the Dutch demanded a court of inquiry due to the deaths of so many Dutch patriots. The inquiry lasted two years and questioned all available German, Dutch and British who had played a part in the operation. The results were inconclusive due to a lack of records. A fire had destroyed most of the records pertaining to the British conduct of this operation (Fuller 1975, p. 170).

There is a school of thought that the British knew of the Abwehr's penetration of this operation almost from the very start and used the operation as a tactic to lead the Germans into believing that the coming D-Day invasion would be via the low countries. This certainly would explain the acceptance of traffic sans the security check for almost two years. The average life of other radio turnbacks averaged three months (Fuller 1975, p. 170). The German officer in charge of Operation North Pole was a Colonel Hermann Giskes. He was captured by the Allies at the end of the war and held until 1948. He was never charged with war crimes. He wrote a book entitled London Calling North Pole (Giskes 1953). It is an excellent record of the entire North Pole experience from the German point of view.

CONCLUSION

The most striking observations presented in this study show how significantly Radio Intelligence contributed to victory, often on a grand scale. The Battle of Tannenburg is an example from the First World War. In the Second World War the best- known use of Radio Intelligence to play a major role in a large victory was the battle of Midway, considered to be the turning point in the Pacific War. In the European Theatre of Op-

erations, the German use of false traffic in Operation North Pole resulted in what Kahn called the greatest Allied defeat in the intelligence war. (Kahn 1968. p. 538). These have been discussed in this paper and serve to demonstrate the great importance of Radio Intelligence.

Being a major source of information, Radio Intelligence was assigned enormous numbers of talented and gifted people as well as huge sums of money and other resources. It is surprising to see how the the democratic countries contributed large sums of money to Radio Intelligence in the years of lean military budgets following the First World War, during the Great Depression and the years up to 1939. These were times when the military machines and military budgets of the United States, Great Britain and France were reduced to a small fraction of their former selves.

The extremely significant results of Radio Intelligence in The First World War, an uneasy peace following the Treaty of Versailles, the growing threat of Hitler and National Socialism, Fascism in Italy and the rise of the Japanese military undoubtedly caused great concern about the nascent coming war. The leaders of that time were apt to embrace Radio Intelligence as a bloodless and cost-effective means of gaining insight into the thinking and actions of potential enemies during peacetime and potentially an effective weapon in the coming war.

Most of the problems of Radio Intelligence are not unique to this endeavor but are, instead, common to all intelligence gathering methods. Perhaps the most frustrating and costly problem is the ignoring of crucial information that was obtained at great cost and risk. Military history is rife with examples of crucial information being ignored and sometimes ridiculed by high-level administrators and political leaders. Many intelligence gathering methods, including Radio Intelligence, are constant on-going operations. As such, they continually consume manpower, funds and other resources. There are other problems unique to Radio Intelligence. Perhaps the most significant is that it can be rendered useless by radio silence.

The evolving political climate and changes in technology make the need for Radio Intelligence greater than ever, but with emphasis on changing targets, end-users and technology. The end of the Cold War reduced but did not eliminate the threat of former enemies. Monitoring the transmissions from the former Communist bloc still continues, although at a reduced level. Many of the resources formerly directed at the Soviet Union are now directed at terrorists and the countries that support them.

Another new target for the attention of Radio Intelligence is the dealers of illegal drugs. The large drug cartels are

well organized, ably managed and richer than many nations. These drug cartels themselves aggressively practice Radio Intelligence by monitoring the transmissions of police and military organizations searching for them.

Changing technology is also affecting the methodology and end-users of Radio Intelligence. These include faster, better computers, better satellite coverage, easily affordable and obtainable cryptography and fiber-optic cable. These have not made modern Radio Intelligence a completely new art, however, since many of the time-tested techniques are still useful.

Technology is expensive, but it can pay off handsomely. This new technology has resulted in a program called Carnivore. With it, NSA has claimed that it can read all radio traffic, e-mail, and computer traffic, fax messages and any other electro-magnetic transmissions anywhere in the world (Bamford 2001, p. 464). A result of this huge harvest of information is a new problem: there is simply too much information to analyze using traditional techniques. As a result, the computers are programmed to seek "key words" in the intercepted traffic. When the computer finds a key word such as "nuclear" or "bomb" the message containing it is then examined. Other messages are filed for possible reference but otherwise ignored.

Another side of the story was presented in *Newsweek* ("Hard Of Hearing", 13 December 1999, p. 78). This article discusses the problem presented by the use of fiber-optic cable and the widespread use of cryptography. Transmitting messages via buried fiber-optic cable effectively precludes interception and analysis because, unlike radio or even telephone wiring, fiber optic cables radiate no interceptable signals. Thus, the *Newsweek* article says, much traffic that would otherwise be transmitted into the ether is sent via buried fiber-optic cable.

There exists a crypto system that is affordable and easily available. This system, called PGP (Pretty Good Privacy) is available to anyone. It is considered to be unbreakable. The traffic that is transmitted via fiber optic cables is encrypted by PGP, potentially leaving the NSA severely handicapped in it's role of gathering and analyzing information.

Radio Intelligence has been and will be crucial in the economic, political and military struggles with foreign powers, organized crime and commerce. The use of Radio Intelligence (now called Signals Intelligence) and the resources committed to it have steadily increased during the twentieth century. The technology, targets and end-users may change over time but the need for it will only increase. No intelligence gathering procedure is perfect. All must be evaluated on a cost-benefit basis. Judged by this criterion, Radio Intelligence played a major role in the Sec-

ond World War and was a major contributor to Allied victory. Its importance cannot be overstated.

REFERENCES

Bamford, James V. (1983). The Puzzle Palace. London: Penguin Books.

Bamford, James V. (2001). Body of Secrets. New York, NY: Doubleday

Brown, Anthony Cave (1975.) Bodyguard Of Lies. New York, NY: Harpercollins.

Breuer, William (1989). Hitler's Undercover War. New York, NY: St. Martin's Press.

Budiansky, Steven (2000). Battle of Wits. New York, NY: Touchstone.

Cain, Gary (1993). "Cost of OSS Radios" In Ranney et al. The OSS Comvets Papers. McLean, VA: The OSS Society.

Drea, Edward J. (1992). MacArthur's Ultra. Lawrence KS: University Press of Kansas.

Elphick, Peter (1997). Far Eastern File. The Intelligence War in the Far East. London: Hodder and Stroughton.

Farago, Ladislas (1967). The Broken Seal. New York, NY: Random House.

Farago, Ladislas (1971). The Game Of The Foxes. New York, NY: D. McKay Co.

Fleming, Ian (1955). Moonraker. London: Jonathan Cape Ltd.

Fricke, W.F. (1954). War Secrets of the Ether. Laguna Hills, CA: Aegean Park Press.

Fuller, Jean Overton (1975). The German Penetration of SOE. New York, NY: Kimber.

Giskes, H.J. (1953). London Calling North Pole. London: The British Book Centre, Inc.

"Hard Of Hearing" *Newsweek*. 13 December 1999. p. 79.

Jones, R.V. (1978). Most Secret War. London: Hodder and Stoughton.

Kahn, David (1968). The Codebreakers. New York, NY: Macmillan.

Kahn, David (1978). Hitlers Spies. London: Hodder and Stoughton.

Kahn, David (1983). Kahn on Codes. New York, NY: Macmillan Publishing Co. Ltd.

Kahn, David (1991). Seizing the Enigma. New York, NY: Barnes & Noble.

Lee, Bartholomew (2002). Radio spies: Episodes in the ether wars. *AWA Review*, 15, 7-97.

Lorain, Pierre (1983). Clandestine Operations. New York, NY: Macmillan.

Masterman, J.C. (1972). The Double-Cross System in the War of 1939-1945. New Haven, CT: Yale University Press.

O'Toole, George J.A. (1991). Honorable Treachery. Boston: Atlantic Monthly Press.

Polmar,Norman (1997). Spy Book. New York, NY: Random House.

Stinnett, Robert B. (2000). Day of Deceit. New York, NY: Touchstone.

Smith, Michael (2000). The Emperor's Codes. London: Bantam Press.

Sterling, George E. (1990). Spies Use Radio. AWA Review, Vol. 5.

Tuchman, Barbara (1958). The Zimmerman Telegram. New York, NY: Ballantine Books.

West, Nigel (1986). Sigint Secrets. New York, NY: William Morrow & Co.

Winterbottom, F.W. (1974). The Ultra Secret. New York, NY: Harpercollins.

Yardley, Herbert O. (1931). The American Black Chamber. Indianapolis, IN: Bobbs-Merrill.

Zacharias, Ellis. (1946). Secret Missions. New York, NY: G.P. Putnam's Sons.

TM 11-476. (1947). Radio Direction Finding

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AWA Review

Fessenden's Christmas Eve Broadcast: Reconsidering an Historic Event

Donna L. Halper & Christopher H. Sterling[1] ©2006

ABSTRACT

Everyone "knows" that Reginald Fessenden conducted the first broadcast of voice and music on Christmas Eve of 1906 . . . or did he? The authors, finding no reference whatever to that event until more than two decades later, explored both the archival and published records of the period and find the iconic event only becomes well known after the inventor's biography, written by his widow, appeared in 1940. A careful search of the available Fessenden documents in two key archives reveals but a single mention of the event—and that in a copy of a 1932 letter. While there is little doubt of Fessenden's earlier transmissions (1900-1906) of voice and music, many of which were witnessed, they have (perhaps ironically) become lost to most historians. This article reviews the published and archival record, and then suggests some reasons for this strange anomaly, including the need to keep such a "frivolous" event from the ears of his financial backers who were seeking success with other lines of wireless business.

The scene is both captivating and widely cited in most histories of broadcasting—especially in this centennial year. Along the Atlantic Coast, on a desolate bluff just south of Boston, on two chilly winter nights a century ago, snow remained on the ground from a storm several days earlier.

> On Christmas Eve and New Year's Eve of 1906, *the first broadcasting* occurred. Three days in advance Reg[inald Fessenden] had his operators notify the ships of the U.S. Navy and of the United Fruit Co. that were equipped with the Fessenden apparatus [a wireless signal detector] that it was the intention of the Brant Rock Station to broadcast speech, music and singing on those two evenings. Describing this, Fessenden [later] wrote:—
>
> "The program on Christmas Eve was as follows; first a short speech by me [Reginald Fessenden] saying what we were going to do, then some phonograph music. ...Handel's 'Largo.' Then came a violin solo by me . . .then came the Bible text, 'Glory to God in the highest and on earth peace to men of good will,' and finally we wound up by wishing them a Merry Christmas and then saying that we proposed to broadcast again on New Year's Eve.
>
> "The broadcast on New Year's Eve was the same as before, except that the music was changed and I got someone else to sing. I had not

picked myself to do the singing, but on Christ mas Eve I could not get any of the others to either talk, sing or play and con sequently had to do it myself. . . .

"We got word of reception of the Christmas Eve program as far down as Norfolk, Va., and on the New Year's Eve program we got word from some places down in the West Indies."[2] (Fig. 1)

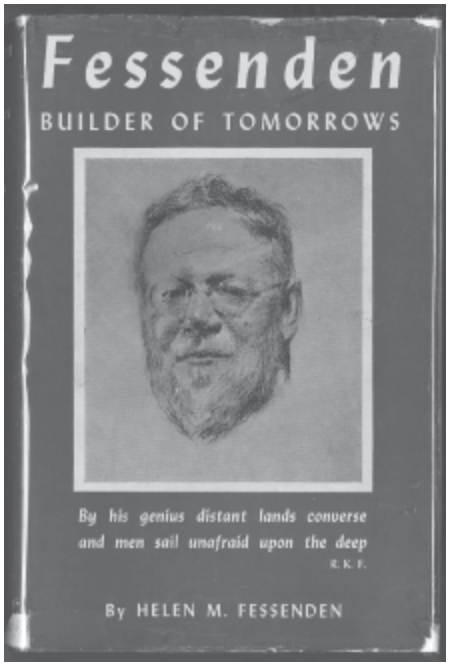
Fessenden
BUILDER OF TOMORROWS
By his genius distant lands converse
and men sail unafraid upon the deep
E. K. F.
By HELEN M. FESSENDEN

Fig. 1. Helen Fessenden's book was published in 1940, eight years after her husband's death. The famous 1906 broadcast is described on pp. 153-4 and the back cover of the dust wrapper claims this was "the First Radio Broadcast."

Questioning the Story

Though widely cited in secondary literature appearing in the decades since (now including the Internet), we find at least two aspects of this charming story rather odd. First and foremost, there appears to have been virtually *no* notice taken of either broadcast at the time (which is what led us to research the event). Despite an extensive search, we have been unable to discover *any* contemporary documents, let alone published reports, that refer to either broadcast. Numerous articles written by Fessenden himself in the weeks and years following those broadcasts make no mention of them.[3] Nor does his own appointment book for 1906.[4] Nor, for example, does an extensive 1910 article about Fessenden's work that covered at least a page in the *Boston Globe*.[5] Nor does a published letter defending Fessenden written by a former colleague in 1914.[6] Nor does Raymond Francis Yates, (formerly editor of *Popular Science)*, who co-authored *The Complete Radio Handbook* in 1922, or Austin Lescarboura (former managing editor of *Scientific American*), in his 1923 book *Radio for Everyone*.[7] Nor did any of the many 1932 Fessenden obituaries in major newspapers or magazines (including those for which he wrote, such as *Radio News*) note such a broadcast.[8] This seems especially odd given the widespread appeal of broadcasting by then, as well as a growing interest in its development.

In the decades since, it appears that most historians and radio history fans have accepted without question Mrs.

Helen Fessenden's detailed account (in her 1940 biography of her husband which appeared 34 years after the events in question) as an adequate and reliable record of what took place, though we don't know whether she was present. For while as noted below, the first published report appeared in 1928, it is only after the appearance of details in her book that the 1906 broadcasts came to be more widely recognized and cited. But if these are the historic, even landmark, events they are now widely thought to be, why were they not recognized as such much earlier?

Second, the statement is odd because Fessenden had already accomplished several *earlier* transmissions of voice and music, from a 1900 experiments from the Outer Banks in North Carolina, to a 1905 demonstration in Washington, DC—as well as a witnessed experiment in wireless telephony that took place at Brant Rock on December 21, 1906, just four days earlier. The only distinction? These were *intended* as point-to-point experiments rather than broadcasts for anyone to receive. Indeed the modern concept of "broadcasting" did not then exist. Though his intent varied, the fact is that voice and music signals were transmitted by Fessenden *before* Christmas Eve 1906. We are *not* questioning his pioneering broadcast role, yet these *earlier* events, despite being better documented, are rarely cited today. How and why, then, did the Christmas Eve and New Year's Eve broadcasts, virtually ignored at the time, achieve such widespread (if not universal) recognition in more recent histories? How have they become landmarks, a part of radio's "accepted" history? Braced by these concerns, and the seeming lack of contemporary supporting evidence, we began our quest for how the story had come to be so widely accepted.[9]

Belatedly Spreading the Word

We began by examining a fairly extensive sample of wireless and radio books written after 1906, and that review soon made clear that despite its iconic reputation now, the Christmas Eve story was not mentioned for more than two decades after it supposedly took place.[10] While Fessenden's wireless work (with the Weather Bureau in 1900-1901, and then with the National Electric Signaling Co, or NESCO from 1902-1910) and his Brant Rock facility are often discussed in early books and articles (those appearing up to about 1920), not one of them mentions any Christmas Eve 1906 broadcast.[11] Of course broadcasting itself was a little known idea until about 1920.

As far as we can determine, the first *published* statement concerning the Christmas Eve 1906 broadcast appeared more than two decades later when Westinghouse vice president H. P. Davis spoke at Harvard University in April 1928, a speech soon included in a book:

Attempts have been

> made, and some successful results had been accomplished prior to the World War, in adapting telephonic principles to radio communications. *Reginald Fessenden, probably the first to attempt this, broadcast a program Christmas Eve 1906.* Later, Mr. Lee DeForest *[sic]* did the same . . .[12]

We find it interesting that a highly complex two-year battle over Fessenden's wireless patent rights had been settled by RCA that very month, granting him a substantial payment for use of his patents, ownership of which had changed hands several times over the previous dozen years.[13] Because of his role within Westinghouse (then part of the RCA patent pool), Davis was well-acquainted with that patent struggle and its settlement which released the parties to comment more freely on past events.

One of Davis's management colleagues at Westinghouse was Samuel M. Kintner (1871-1936), who is an important figure in the Fessenden story. Kintner had been an undergraduate student under Fessenden at Purdue in the 1890s, served as one of his graduate assistants at the University of Western Pennsylvania (after 1908 the University of Pittsburgh), and then became a faculty member there, following his mentor. He joined Westinghouse in 1903 and later became a research official there. Kintner had served as manager and then bankruptcy receiver for the failing NESCO in 1911, at which point he and Fessenden appear to have ended their friendship. He returned to Westinghouse and both he and Davis also served on the board of the International Radio Telegraph Co. when it purchased NESCO's Fessenden patents. In complex 1920 arrangements, Westinghouse purchased control of the Fessenden patents, reselling them immediately to RCA—which ended up paying the settlement to Fessenden in 1928.

Eight years later, Alvin Harlow's history of telecommunications referenced (but did not document) the Christmas Eve event.[14] And the first volume of Gleason Archer's massive radio history, appearing in 1938, cited Harlow's report to retell the story.[15] With the appearance of Helen Fessenden's biography in 1940, references to the Christmas Eve story begin to pick up. Orrin Dunlap, by then with RCA after years as radio editor for the *The New York Times*, noted it in a biographical anthology four years later, though he had not mentioned it in his several earlier volumes on radio.[16] Robert Landry, the widely-read editor of *Variety*, repeated the story in his popular postwar survey of radio.[17] Numerous other references appeared through the 1950s, though if they were documented at all, they referenced Helen Fessenden's book.

The huge 50th anniversary issue of the Institute of

Radio Engineers journal in mid-1962 cited the Christmas Eve event as the "First documented, successful broadcasting," suggesting the engineering community accepted the notion, even though the "documentation" was, again, that of Mrs. Fessenden's informal biography.[18] So did Howeth's fine history of naval radio issued a year later, though it mentions the event only in a chronological appendix.[19] Three years later, the first volume of Erik Barnouw's historical trilogy on broadcasting reproduced the story, quoting Harlow and citing Helen Fessenden–thus giving the story further substantial support.[20] So did two later scholarly assessments which were otherwise well documented: Hugh Aitken's study of early radio,[21] and Frederick Seitz's monograph on the inventor's life.[22] But in this case neither provided any citation for the Christmas Eve 1906 story.

Clearly the Fessenden 1906 broadcasts are now widely accepted as historical facts and important firsts. As the centennial of the broadcasts approaches, the story is again cropping up. Researcher James Brittain referenced its 90th anniversary in an IEEE journal.[23] And prolific technology historian Russell Burns includes it in his documented history of communications technology.[24] Yet another version appeared in *Invention & Technology*,[25] and one retrospective piece ran in the *Boston Globe* as we were researching this paper.[26] The Internet is rife with pages on Fessenden which cite the "eves" broadcasts. Doubtless more accounts have appeared and will continue to do so. But what are the facts?

Fessenden's Brant Rock Station

Brant Rock (Fig. 2) lies on the Massachusetts coast some 30 miles south of Boston, near Marshfield and just south of Plymouth. It was a pretty

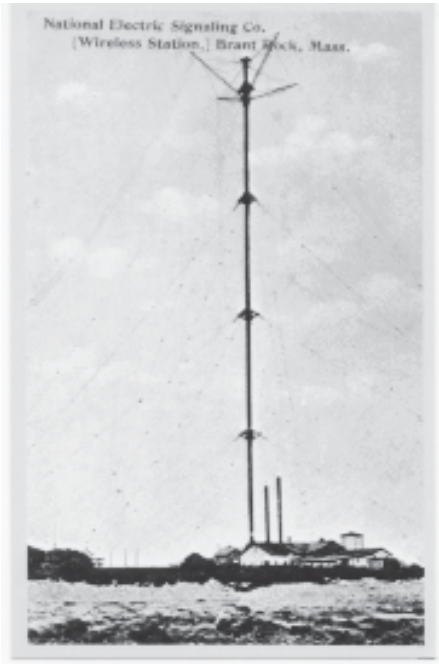

Fig 2. This period postcard view makes clear how dominant the 420-foot tubular tower tower with its cable stays was. Most of what we can see here is long gone, with two exceptions. Two houses survive as private residences, more than a century after the station began operation. The main buildings which included transmitter and other equipment, along with the tower, were taken down after NESCO went into receivership. The fact that many postcards exist for the station attests to its popularity at the time.

desolate spot a century ago. And in that desolation lay part of the appeal for locating an experimental wireless transmitter, far from prying eyes and potential local sources of electrical interference. The facility's 420-foot tubular steel antenna, transmission building and support structures were constructed in 1905, completed at the end of December. On January 2, 1906, the Brant Rock wireless station, owned by NESCO which then employed Fessenden (at a salary of $300 a month–a very respectable salary in that time), began sending wireless Morse code communications to a sister facility across the Atlantic in Machrihanish, on the West coast of Scotland. Soon Brant Rock picked up the first transatlantic reply to the effect that the Brant Rock condensers worked satisfactorily. Within several months, operators at the Scottish station reported hearing voices for the first time, accidentally overhearing a conversation between radio operators in Brant Rock and nearby Plymouth.[27] These were probably the first voice transmissions across the Atlantic.

Then, on December 6, 1906, calamity struck when the antenna tower at the Scottish station (the same design as the tall metal tube used at Brant Rock) was blown down in a gale, apparently due to defectively installed guy wires.[28] As the facility was not rebuilt (NESCO's supporters apparently declined to foot the cost), this ended Fessenden's promising trans-Atlantic tests.

Late in 1906, after installation of a 2 kw alternator transmitter manufactured by General Electric, the Brant Rock station conducted a witnessed demonstration of its wireless telephony capabilities. Among those to whom invitations were mailed on December 11 and 12, 1906 [29] were such major companies as Bell Telephone in Boston and Westinghouse, technical journals (*The American Telephone Journal, Scientific American),* the Associated Press, foreign embassies (of Britain, France, and Germany), particular individuals (Arthur Kennelly of Harvard who was unable to be present, Elihu Thomson who did attend as a representative of General Electric, and Peter Cooper Hewitt, a noted wireless inventor), as well as a representative of the U.S. Patent Office. We know that at least one trade magazine journalist (John Grant of the telephone journal), AP reporters Keating and Davis, Thomson of GE, and Greenleaf W. Pickard representing AT&T were present on that chilly winter day. [30]

Fessenden's "programme for telephone tests" issued with the invitations on December 11th, called for a schedule of 20-minute segments of material to be transmitted between Brant Rock and Plymouth. These included use of a "phonograph advertising record" for 2.5 minutes followed by two 5-minute periods of "talking by operator" and a final "five minutes advertising

record on the phonograph." The record, despite the term describing it, included a violin solo, and this test thus appears to have included both voice and music transmissions.[31] According to one witness, the Friday afternoon demonstration transmitted these sounds the 11 miles separating Brant Rock from the waterfront reception site in Plymouth, most of that distance being over water which aided the transmission. Sound quality varied as did loudness of the signal, though speech was picked up better than the recorded music. [32] An unnamed representative of the Bell interests (either Pickard or another engineer) returned the very next day for a repeat performance of some of the tests.[33]

A vital distinction to be made is that one can argue this clearly constituted a *broadcast*—voice and music sent out over the air, even if it was only intended for reception by a single station. Anybody with the proper equipment within range of the transmitter could have picked it up. By combining voice and music (as opposed to code) with radio waves, Fessenden provided a very basic broadcast in effect, even if not in intent. The Christmas/ New Years Eve 1906 transmissions differed only in that they were *intended* for anyone who could hear them (yet even in this case, apparently U.S. Navy and United Fruit ships, some of which used Fessenden or Fessenden-like receiving apparatus, were notified in advance, so the intent is very similar to the December 21st witnessed experiment).

Many more tests of both wireless telegraphy and telephony were conducted at the station in the months and years to come, though Fessenden eventually fell out with his financial backers. Fessenden had left the scene and NESCO by 1911, and Brant Rock's 420-foot antenna tower was apparently torn down in 1912 or 1913, leaving little behind.[34] As a local paper noted in a centennial observation,

> Today, the remnants of the original radio signal tower — bare slabs of reinforced concrete, conical porcelain insulators sandwiched in between, and a huge bell-shaped pivot point on top — are nestled behind homes in Blackman's Point trailer park, far from view.[35]

Interestingly, a few of the station buildings of the 1906-11 period still survive—the transmission shack and the home and office used to house operators are presently private residences.

Seeking Substantiation

Not surprisingly, we found that information about Fessenden abounds in the early periodical literature on wireless.[36] While the earliest published reference we have located that refers to the Christmas Eve 1906 event dates to the previously noted H. P. Davis lecture and book chapter of 1928, a handful of newspaper stories

early in the 1930s also began to mention the broadcast. The first we've been able to find appeared in November 1930, written by reporter Robert Mack of Consolidated Press. Discussing the tenth anniversary of KDKA, he traced broadcasting back to Christmas Eve 1906, much as H. P. Davis had done in his 1928 lecture.[37] Two years later, *The New York Times* in a May 1932 story reported on a recent paper by Westinghouse's Samuel M. Kintner, who outlined Fessenden's career and—something Kintner had not done before—offered details about the Christmas Eve broadcast.[38] The *Times* also featured radio and technology columnist T. R. Kennedy Jr. who championed the Christmas eve event, which he mentioned in several 1940 and 1941 articles. But for the most part, newspapers and magazines of the period made no reference to Fessenden's Christmas eve broadcast.

In addition to the Fessenden-authored series of autobiographical articles that ran in *Radio News* through much of 1925 (which made no mention of the Christmas eve event), many other popular journals reviewed the inventor's work, though none mentioned the Christmas Eve broadcast until after the 1940 appearance of Helen Fessenden's book. In 1945, for example, the respected weekly magazine *Science*, in an article about the 25th anniversary of KDKA, noted, "The first radio broadcast in history, it is claimed, was on Christmas eve 1906, from the Fessenden station at Brant Rock, Mass." [39] And by the early 1950s, inclusion of the Christmas Eve broadcast was a common part of syndicated "Today in History" columns.[40]"

Frustrated with the published record, our search for earlier material thus turned to relevant primary documents. In Fessenden's case that is a mite complex given the number of different employers (the Weather Bureau and NESCO chief among them) and parties involved. There are two important archives holding substantial Fessenden papers—the first was gathered over many decades by George Clark and is now housed at the Smithsonian's National Museum of American History in Washington, DC.

The Clark "Radioana" collection proved fascinating but a search of 15 boxes of the most relevant NESCO/ Fessenden material revealed no "smoking gun" document proving that the Christmas Eve event ever took place–or, indeed, even mentioning such an event. We did find confirmation of the December 21st witnessed demonstration at Brant Rock, as well as references to numerous earlier tests elsewhere. And we found a crucial 1932 letter from Fessenden to Kintner that is the *only* mention by the inventor of the Christmas Eve broadcast. More on that below. The remaining records are, after a century and more, incomplete. For example, in the Clark archive we found Brant Rock station record books for

1905 and early 1906, and some for 1912 (by which time Fessenden had left), but nothing in between—including the period of focus here. Presumably those records once existed. Likewise surviving scrapbook collections of newspaper clippings were tantalizingly incomplete and did not include the critical 1906-7 period.

Fessenden's personal papers were deposited in the North Carolina state archives (in Raleigh) by his son in 1944, a dozen years after his father's death, and only shortly before his own.[41] This is an extensive collection covering the inventor's whole life, and thus includes much that does not relate to the question at hand. Indeed most of this collection contains material after our 1906-07 period of interest. A careful search of the relevant wireless material across nearly 30 boxes of this collection failed to find a single reference to any Christmas Eve broadcast. Thus, to our disappointment, we found that neither of the archives holding primary Fessenden material provides any contemporary evidence to support the oft-reported story.

Earlier Fessenden "Broadcasts"

What makes the iconic nature of the Christmas and New Years Eve broadcasts odd to us is that the widely-cited broadcasts were far from Fessenden's first ventures in radio telephony. He conducted several earlier demonstrations, held in at least three different states between 1900 and 1905.

Maryland, for example, claims it all began six years prior to the Christmas Eve broadcasts. An official state historical roadside marker states

Milestone in Radio History

"Here, on Cobb Island, in December 1900, Reginald Aubrey Fessenden, assisted by Frank W. Very, while experimenting in wireless telephony, for the first time sent and received intelligible speech by electromagnetic waves between two masts 50 feet high and one mile apart." (see Fig. 3)

MILESTONE IN RADIO HISTORY
HERE, ON COBB ISLAND, IN DECEMBER, 1900, REGINALD AUBREY FESSENDEN, ASSISTED BY FRANK W. VERY, WHILE EXPERIMENTING IN WIRELESS TELEPHONY, FOR THE FIRST TIME SENT AND RECEIVED INTELLIGIBLE SPEECH BY ELECTROMAGNETIC WAVES BETWEEN TWO MASTS 50 FEET HIGH AND ONE MILE APART.
MARYLAND HISTORICAL SOCIETY

Fig. 3. Maryland historical marker on Cobb Island along the Potomac River south of Washington, DC.

Fessenden's wireless experimentation lab was located some 50 miles southeast of Washington, DC, on Cobb Island, on the north shore of the Potomac River. He and his assistant Alfred Thiessen perfected Morse transmissions using a new generator and in October 1900 he experimentally hooked up a microphone (a telephone handset) to his apparatus. On December 23, 1900 Fessenden said into his microphone, "One, two, three, four. Is it snowing where you are Mr.

Thiessen? If so telegraph back and let me know." Thiessen replied by telegraph in Morse code that it was indeed snowing. In great excitement Fessenden wrote at his desk, "This afternoon here at Cobb Island, intelligible speech by electromagnetic waves has for the first time in World's History been transmitted." [42]

This was six *years* before the widely-cited Brant Rock transmissions and almost a year before Marconi's transmission of the wireless telegraph code letter "S" from Poldhu, England to Signal Hill, Newfoundland. Fessenden's employer, then the U.S. Weather Bureau, was pleased and Willis Moore, his immediate supervisor, suggested shifting experiments to North Carolina to test wireless signaling between Cape Hatteras, Roanoke and another mainland location to create a 100-mile triangle.[43]

And thus North Carolina chimes in with its own moment in the sun, with roadside sign B53 on the Outer Banks near Cape Hatteras, placed in 1988:

Radio Milestone

"From near here in 1902 R.A. Fessenden sent the first musical notes ever related *[sic]* by radio waves. Received 48 miles north." (see Fig. 4)

And both the 1900 Maryland and 1902 North Carolina events do, indeed, show up in the literature of the time. For example, a Boston paper spoke of "wireless words" being sent clearly upwards of 200 miles or more, with many improvements

RADIO MILESTONE
From near here in 1902
R. A. Fessenden sent the
first musical notes ever
relayed by radio waves.
Received 48 miles north.

Fig. 4. North Carolina historical road marker B-53, erected not far from Cape Hatteras on the state's Outer Banks.

expected to come.[44] And it happened again when on February 13, 1905, witnesses saw Fessenden transmit "words, sentences and tunes" from the Forsberg & Murray Yard, at 8th and Water Streets in Washington, D.C.[45] Yet modern citations of these documented early transmissions of wireless telephony now seem all but lost to posterity.

Evidence versus Event

We are *not* arguing here that Fessenden's Christmas and New Year's Eve broadcasts never took place. For one thing, proving a negative after a century is nearly impossible. Nor do we question anybody's role or intentions–we are not accusing anybody of doing anything. What we do continue to question, however, is (a) why there are so few references to these now-legendary broadcasts prior to Helen Fessenden's 1940 biography of her husband, and, just as curious, (b) why *documented and earlier* Fessenden wireless telephony tests that most assuredly took place are today all but forgotten? Do we

know about the Christmas Eve event today mainly because of a romantic date connection that has slowly became accepted over the decades?

The absence of any reports in contemporary (or later) press or periodicals (prior to about 1940, that is) suggests several potential explanations. Among them, of course, though thoroughly unprovable at this juncture, is the unlikely possibility that the famous broadcasts never happened and were merely a fault of memory or an invention of later years. Given that most early wireless pioneers actively sought (and received) publicity for their efforts, the lack of any press attention then or later does at least raise questions about whether journalists even knew of these broadcasts, let alone thought them important. There are widespread press, journal, and book references to Fessenden's many other accomplishments—just not this one.

There are several possible reasons the broadcasts were ignored in the press. For one, Fessenden was not good with most reporters — his own ego and certitude of his superiority in wireless development got in the way of effective press relations time and again. Another circumstance, entirely beyond his control, was that during the last weeks of December, a contentious battle broke out between the dominant New England Telephone Company and an upstart independent which sought permission to compete in Boston. The so-called "telephone wars" dominated the city's newspapers,[46] keeping reporters busy at the very time when some might otherwise have covered other stories–such as the wireless events at Brant Rock.

Another possible option is that the "eves" broadcasts were later confused for events for which contemporary evidence clearly exists. Here, the most likely scenario is that the witnessed December 21, 1906 experiment over time might have been confused with Christmas Eve, a mere three days later. After all, the content of both was similar. Of course the earlier transmission was directed from one station to another as opposed from one station to any who might listen—seemingly the aim of the Christmas and New Year's Eve events. Despite advance notice supposedly given to U.S. Navy and United Fruit company vessels three days before the 1906 broadcasts, however, we could find no surviving record of any such notice.[47] While their *intent* may have differed, the voice and music content of the two December 1906 broadcasts was very similar, though the earlier event was apparently about half as long. *The fact remains that Fessenden is almost definitely the first man to broadcast.*

The likelihood of this is strengthened by the single piece of written evidence that the Christmas and New Years Eve broadcasts actually happened. Writing from Bermuda on January 29, 1932, Fessenden, in response to a now-lost inquiry

from Samuel Kintner of Westinghouse, stated

> By broadcasting I suppose you do not mean the transmission of speech, music and singing to other stations for the same firm which is sending but to receiving stations operated by other firms than the sending station, and also programs advertised or notified in advance.
>
> If you mean by broadcasting the transmission of speech, music and signing *[sic]* to other stations of the same ownership as the transmitter, then the program given to Dr. Kennelly,[48] Prof. Elihu Thompson, the engineers of the Western Electric and A. T.& T. and other companies, and the editors of several of the New York Papers at the exhibition which you will find described in the American Telephone Journal, January 26th and February 7th, 1907, would be a broadcast, *as indeed would be the exhibitions of wireless telephony between Washington and Annapolis in 1903, and 1905.* (Emphasis added)
>
> If, however, you do not call this a broadcast, then the program sent out Christmas Eve and New Year's Eve, 1906 would be the first broadcast. This broadcast was advertised and notified three days in advance of Christmas, the word being telegraphed to the ships of the U.S. Navy and the United Fruit Co., which were equipped with our apparatus that we intended broadcasting speech, music and singing on Christmas Eve and New Year's Eve.[49]

What we find fascinating and telling about these paragraphs is that Fessenden himself suggested three differing definitions of what a broadcast could be, his own example of each, and then left the decision to Kintner. The latter chose the Christmas Eve event (Fessenden's third option)—but he was making his decision after a dozen years of established broadcasting, rather than in the very different context of 1906 when the whole concept was new.

Another possibility is that information about the Christmas Eve event was suppressed at the time for business reasons. A detailed report on the state of his experimentation, written by Fessenden to his backers on January 1, 1907—seemingly less than 24 hours after the second reputed broadcast, makes no mention of them.[50] Fessenden's investors were supporting the inventor's effort to create a viable point-to-point system of wireless telegraphy to compete with telegraph cables as well as other

wireless systems. The inventor, already suffering friction with those backers,[51] might well have preferred they not find out about a wireless telephony experiment that seemed unrelated to that system. Still, it seems odd that no mention or record of either of the supposed broadcasts is evident even in the inventor's private communications or files.

There is another option—caution. Fessenden noted in 1918 that he had not claimed the feat of having sent a voice signal across the Atlantic back in 1906 due to the many false claims made by other inventors—and his inability to prove the case after the antenna tower collapsed at the Scottish station in 1906 and was not subsequently rebuilt.[52] He may have felt much the same about the supposed Christmas and New Year's Eve broadcasts, especially after the witnessed and reported December 21, 1906 transmissions. Yet while that may have been the case at the time, surely it was no longer so even a few years later? Radio magazines of the time might not have mentioned the "eves" as they were well aware that Fessenden had already broadcast voice and music signals earlier than late 1906.

One final option is that the broadcasts were simply considered as fun—a holiday celebration by a few key staff members, not worthy of further serious notice, let alone being recorded for posterity. Given Fessenden's earlier transmissions of voice and music, the Christmas Eve and New Year's Eve events were not technical landmarks, but may be seen as just a bit of seasonal fluff by the staff. But even if this is the case, we find it strange there is absolutely *no* reference to the events in the archival material that survives. It seems odd that *nobody* supposedly present—friends, colleagues or co-workers—ever mentioned the broadcasts at all, even in later years. Yet even those who knew his wireless telephony work sometimes failed to attach importance to it.[53]

Finally, we stress again that our research does not in any way seek to diminish the credit that Reginald Fessenden clearly deserves as the first man to send voice and music signals through the air by wireless. There is little question he accomplished that—whether in late 1906, or on several earlier occasions as is well documented. His was the innovative spark that set others on the path toward the widespread radio broadcasting of today. But so far as we can determine, neither Christmas nor New Year's Eve of 1906 marked the true *first* broadcast.

Notes

1. We acknowledge the vital support of the Shiers Memorial Fund in our archival work and travel related to researching this paper. George and May Shiers, through their several bequests, continue to support valuable research efforts. See Christopher H. Sterling, "Television Historian: An Appreciation of George Shiers (1908-83)," in this issue of the *AWA Review* (2006). We also very much appreciate the comments, suggestions and occasional tweaks from Michael C. Keith of Boston College. He was an important cheerleader in this process. And we are grateful for the many good questions and suggestions (which helped to tighten the manuscript) from John Michael Kittross, retired professor at Emerson College. Finally, though we substantially disagree on many aspects of this story, we appreciate the many comments of John Belrose, a Canadian radio engineer who has written extensively about Fessenden's career.

2. Helen M. Fessenden, *Fessenden, Builder of Tomorrows* (New York: Coward McCann, 1940; reprinted by Arno Press, 1971), pp. 153-154, italics in the original. The author, the inventor's widow, died of a heart attack only months later, in April 1941. To *whom* or *when* her husband wrote these details is not identified in her biography, but quotes exactly from a letter written by Fessenden to Samuel M. Kintner, then Vice President of Engineering at Westinghouse, on January 29, 1932, six months before the inventor's death, and in response to a request (now lost) for information from Kintner dated January 9th. See Clark "Radioana" Collection, Smithsonian Archives, Letter of January 29th, 1932, Reginald A. Fessenden to S.M. Kintner, CWC 135-246A. See also: Elliot Sivowitch, "Broadcasting's 'Pre-History, 1876-1920," *Journal of Broadcasting* 15:1 (Winter 1970-71) at p. 19, note 24. As noted below, Kintner included a reference to the Christmas Eve broadcast in a paper he delivered later in 1932.

3. See, for example, these papers, all by Fessenden: "Recent Progress in Wireless Telephony," *Scientific American* (January 19, 1907), pp. 68-69, which refers to the witnessed December 21st experiments; "The Continuous Production of High Frequency Oscillation," *The Electrician* (February 22, 1907), p. 710, which also notes the earlier December experiment; "Wireless Telephony," *Transactions of the American Institute of Electrical Engineers*, 27:1283-1358 (June 1908), reprinted as "Wireless Telephony" in *Smithsonian Report 1908* (Washington: Government Printing Office, 1908), pp. 161-195; and "Wireless Telephony," *Scientific American Supplement*, 67:172-174, 180-182, 196-198 (March 13 and 27, 1909) which are excerpts from the 1908 paper. While each of these refers to the December 21, 1906 witnessed wireless telephony demonstration, *none* mentions any Christmas or New Year's Eve broadcast.

4. Fessenden's annual appointment books for several years in the early 1900s are found in the Fessenden Papers, State Archive of North Carolina, Box 1140.100. The 1906 book contains no entries after October 8, 1906, though all pages are present

5. "Wireless Station at Brant Rock Has Been In Touch with Egypt," *Boston Globe* (June 26, 1910), p. SM 3.

6. "Wireless Telephony" Letter to the editor from S. M. Kinter, *New York Times* (May 21, 1914), p. 10.

7. Raymond Francis Yates and Louis Gerard Pacent, *The Complete Radio Book* (New York: Century, 1922) briefly notes Fessenden (but not the broadcasts) on p. 294; and Austin C. Lescarboura, *Radio for Everybody* (New York: Scientific American Books, 1924) which is largely "how-to" in orientation.

8. See, for a telling example, "In Memoriam: Reginald Aubrey Fessenden." *Radio News*, 14:6, pp. 334-5 (December 1932). This journal had carried Fessenden's own autobiographical series of columns just a few years earlier.

9. As with many other fields of study, myths in radio have often become part of generally accepted history.

One example underlines the point—the often-retold story of David Sarnoff manfully taking down the names of *Titanic* survivors in April 1912 as President Taft ordered all other wireless operators off the air. Gripping, heroic—and totally untrue. While it never happened (as even a scan of contemporary newspapers would have made clear to anyone who looked), it took Kenneth Bilby's *The General: David Sarnoff and the Rise of the Communications Industry* (New York: Harper & Row, 1987) to finally put that tale to rest with the facts on Sarnoff's real and more limited role.

10. We would be happy to share the full list of all the material we looked at—books, magazines, journals, primary documents—merely send the senior author an email. She can be reached at dlh@donnahalper.com .

11. Books of this period often demonstrate a national bias, emphasizing the work of fellow-countrymen (e.g., British books usually tout Marconi or Fleming, while American authors speak more of Fessenden or de Forest). Among several representative examples (and, as noted in the previous note, we are happy to demonstrate that we checked many more):

James Erskine-Murray's translation of Ernst Ruhmer's *Wireless Telephony in Theory and Practice* (London: Crosby, Lockwood, 1908)—one of the first books devoted to the subject–includes details on the 21 December 1906 event but makes no mention of any Christmas Eve broadcast. Erskine-Murray exchanged several letters with Fessenden in mid-1907 to be sure he had Fessenden's work accurately described—but there was no mention of Christmas Eve broadcasts in those letters [Clark "Radioana" archive, Smithsonian Archives, box 384].

James Erskine-Murray, *Wireless Telephones and How They Work* (London: Crosby, Lockwood, 1910), makes several references to Fessenden's work and includes a photo of the Scottish station whose tower had been destroyed by wind four years earlier–but does not mention any Christmas Eve broadcast.

A. P. Morgan, *Wireless Telegraphy and Telephony Simply Explained* (New York: Munn, 1912), on p. 128 includes a photo of the "Fessenden wireless telephone transmitting phonograph music," almost definitely at the Brant Rock station, but does not note any Christmas Eve event.

Charles G. Ashley and Charles B. Hayward, *Wireless Telegraphy and Wireless Telephony* (Chicago: American Technical Society, 1916); and Alfred M. Goldsmith, *Radio Telephony* (New York: The Wireless Press, 1918): neither notes the broadcasts, though both mention Fessenden's work (and Goldsmith includes photographs of the Brant Rock station).

Year-Book of Wireless Telegraphy and Telephony (London: Wireless Press, 1913 to 1925 inclusive): none of the 13 annual volumes mentions such an event, though there is occasional reference to Fessenden.

John V. L. Hogan, *The Outline of Radio* (Boston: Little, Brown, 1928, 3rd ed.) rather tantalizingly notes, on p. 20, "It is well known, however, that in 1906, Fessenden gave numerous practical demonstrations of radio-telephony between his experimental stations at Brant Rock, and Plymouth, Massachusetts..." but then moves on to later developments. Hogan was himself an active radio innovator.

12. H. P. Davis, "The Early History of Broadcasting in the United States," in *The Radio Industry: The Story of Its Development* (Chicago: A. W. Shaw, 1928; reprinted by Arno Press, 1971), pp. 189-225, at p. 190, emphasis added. The April talk, focused heavily on station KDKA, was initially issued as a free-standing booklet. Davis repeats the claim with almost the same sentence in his "American Beginnings," in Martin Codel, ed. *Radio and Its Future* (New York: Harper, 1930), p. 4. As best we can tell, the first published article connecting Fessenden with later (KDKA) events in Pittsburgh appeared in 1923: "R.A. Fessenden: A Pioneer in

Perfecting Radio Phone: Pittsburger's *[sic]* Idea, Presented 20 Years Ago, Contained Factors Which Made Modern Radio Telephony Possible," *Boston Globe* (July 15, 1923), p. 52. Fessenden had taught in the late 1890s at what is now the University of Pittsburgh, and Kintner had been one of his assistants there.

13. The suit, brought against RCA by Fessenden in 1926, resulted in a settlement that paid the inventor a half million dollars—easily worth at least $5 million in modern values—for the rights to use his wireless patents received during the first decade of the century. See W. Rupert Maclaurin, *Invention and Innovation in the Radio Industry* (New York: Macmillan, 1949), p. 135. See also Reginald Fessenden, "Brief Statement of Case," seven page typed mss dated November 15, 1924, Fessenden Papers, State Archive of North Carolina, box 1140.89. Samuel Kintner was a primary witness early in the proceedings. See "Trade Board Rules in 'Radio Trust' Suit," *New York Times* (April 13, 1926), p. 12. Interestingly, while in his own 1925 talk on radio development, Kintner made no mention of the Christmas Eve 1906 broadcast, he did include it in his later (undocumented) paper: "Pittsburgh's Contributions to Radio," *Proceedings of the IRE,* 20:1849-1862 (December 1932) at p. 1852.

14. Alvin F. Harlow, *Old Wires and New Waves: The History of the Telegraph, Telephone, and Wireless* (New York: Appleton-Century, 1936; reprinted by Arno Press "Telecommunications," 1974), p. 455.

15. Gleason L. Archer. *History of Radio to 1926* (New York: American Historical Society, 1938; reprinted by Arno Press "History of Broadcasting," 1971), p. 86.

16. Orrin E. Dunlap, Jr. *Radio's 100 Men of Science* (New York: Harper, 1944), in his mini-biography of Fessenden, p. 139.

17. Robert K. Landry, *This Fascinating Radio Business* (Indianapolis: Bobbs-Merrill, 1946), p. 22.

18. Raymond F. Guy, "AM and FM Broadcasting," *Proceedings of the Institute of Radio Engineers,* 50:811 (May 1962). On examination, the documentation refers back to Archer, note 15 above.

19. L. N. Howeth, *History of Communications-Electronics in the United States Navy* (Washington: Government Printing Office, 1963), p. 521. Howeth provides a wealth of documented detail on Fessenden's work, facilities, and battles with the Navy over patent rights, but otherwise makes no mention of any Christmas Eve broadcast.

20. Erik Barnouw, *Tower of Babel: A History of American Broadcasting to 1933* (New York: Oxford University Press, 1966), p. 20.

21. Hugh G. J. Aitken, *The Continuous Wave: Technology and American Radio, 1900-1932* (Princeton, NJ: Princeton University Press, 1985), pp. 74-75.

22. Frederick Seitz, *The Cosmic Inventor: Reginald Aubrey Fessenden, 1866-1932* (Philadelphia: American Philosophical Society, 1999), p. 30. This is the best modern exposition of the inventor's life and accomplishments. With Helen Fessenden's book (note 2) and Ormond Raby, *Radio's First Voice: The Story of Reginal Fessenden* (Toronto: Macmillan, 1970), written for younger readers, there are but three monograph's on the inventor, each with drawbacks. A definitive and documented biographical study is badly needed.

23. James Brittain, "Reginald Aubrey Fessenden and the Origins of Radio," *IEEE Proceedings,* 84:1852-53 (December 1996), includes three photos, but sadly no documentation of any kind. In his earlier book on alternator inventor Ernst Alexanderson (see note 30), Brittain made no mention of the Christmas Eve broadcasts.

24. Russell W. Burns, *Communications: An International History of the Formative Years* (London: IEE, 2004), p. 325. Burns cites as his source John S. Belrose, "Fessenden and the Early History of Radio Science," *Proceedings of the Radio Club of America* (November 1993), pp. 6-23. Belrose, a Canadian engineer, has written at least three documented

papers about Fessenden's work, and has others under way.

25. William S. Zuill, "The Forgotten Father of Radio," *Invention & Technology* (Summer 2001), pp. 40-47. The author edited the Bermuda newspaper.

26. Carolyn Y. Johnson, "Radio Days at Brant Rock: 100 Years Ago, A Marshfield Station Created a Buzz That's Still in the Air," *Boston Globe* (January 1, 2006): http://www.boston.com/news/local/articles/2006/01/01/radio_days_at_brant_rock/

27. Reginald A. Fessenden, "The First Transatlantic Telephone Transmission," *Scientific American* (September 7, 1918, P. 189, notes that the Scottish operator sent a registered letter to Brant Rock, reporting the inadvertent pick up. See also Helen Fessenden, op cit., pp. 154-155.

28. "Trans-Atlantic Wireless Telegraphy," *Engineering* (January 18, 1907), p. 89 includes photos and diagrams of what happened to the antenna support wires. Interestingly, Marconi had similar wind problems with antenna towers at many of his early transmitters.

29. While widely cited in the literature, many sources mistakenly report that the demonstration itself took place on December 11th. Checking with the documents in the Clark "Radioana" archive and the Fessenden Papers in North Carolina confirms that date was actually when invitations to *attend* the event were mailed. The letter of invitation is also reprinted in Fessenden, "Wireless Telephony," AIEE, op cit, p. 1309, note 1.

30. "Wireless Telephone Tests at Brant Rock and Plymouth, Mass." Eye-witness account typescript of eight pages dated [ironically!] December 24, 1906, p. 1. Clark "Radioana" Archive, Box 74, folder 2. The author is not identified, but was Greenleaf Pickard of AT&T, as identified in James E. Brittain, *Alexanderson: Pioneer in American Electrical Engineering* (Baltimore: Johns Hopkins University Press, 1992), p. 43. The account also appears as an appendix in Erskine-Murray (1908), op cit. It seems odd that despite the presence of two AP reporters–both referenced in the eyewitness typescript—no story seems to have resulted. We have not only checked a substantial cross-section of newspapers (see note 10) for the days following the demonstration, we have also checked with AP's archives. Indeed, Fessenden had wondered as well–he sent a telegram on December 30th to his backers asking "if Associated Press intended publishing account of tests" and was told by a reply the next day that his backers had inquired and "had no intimation from [AP] as to any publication." Fessenden Papers, State Archive of North Carolina, Box 1140.6, file 2.

31. "Programme for Telephone Tests," dated December 11, 1906, and signed by Fessenden. Clark "Radioana" Archive, Box 74, folder 2. The spelling of "programme" reflects Fessenden's Canadian birth.

32. "Wireless Telephone Tests..." op cit. See also John Grant, "Experiments and Results in Wireless Telephony," *The American Telephone Journal* (January 26, and February 2, 1907), pp. 49-51, 68-70, 79-80.

33. Fessenden Papers, State Archive of North Carolina, Box 1140.6, file 2.

34. Helen Fessenden, p. 341. Some other sources suggest the tower may have come down as late as 1917.

35. Johnson, op cit (note 26).

36. See, for example, "Wireless Station at Brant Rock has been in Touch with Egypt," cited in note 5. Its review of Fessenden's experimental work was based, in part, on an interview with the inventor. No mention of any Christmas Eve broadcast appears.

37. Robert Mack, "Broadcasting by Radio Came into Being Decade Ago," as printed in the *Appleton [Wisconsin] Post-Crescent* (November 1, 1930), p. 10. Mack wrote for the Consolidated Press, a now-defunct syndicated news service, and the story presumably ran in many other papers as well. It appears to have been prompted by the 10th anniversary of KDKA which figures largely in his

narrative.

38. Orrin E. Dunlap Jr. "Broadcasting Voice by Radio was a Goal of the Pioneers," *New York Times* (May 8, 1932), X:10. Dunlap's story was based on the just-published paper by Kintner in the *IRE Proceedings* cited at the end of note 13.

39. "The Twenty-Fifth Anniversary of Broadcasting." *Science*, New Series (October 19. 1945), p. 14.

40. See. for example, "In December—A List of Coming Events, Anniversaries, and Other Noteworthy Dates," *New York Times* (December 2, 1951), p. 22.

41. Colonel Reginald Kennelly [sometimes cited as Kenneth which is incorrect] Fessenden (1893-1945), was the only child of Reginald and Helen. After some discussions with the Fessenden National Memorial Association (an organization now apparently defunct) and the North Carolina Department of Archives and History, in August 1944, he donated his father's papers to the state archives where they remain today. Col. Fessenden was lost at sea off Bermuda while sailing on June 22, 1945. His body was never found, and about nine months later, Bermuda officials officially ruled that he was dead.

42. See Alfred C. Pickells, "Early Experiments in Wireless Telegraphy," *Modern Electrics* (December 1913), pp. 954-957.

43. A quarter century ago, the state of North Carolina considered developing the site of Fessenden's wireless operation near Cape Hatteras as a state park. See *Fessenden Park in Dare County, North Carolina: A Master Plan and Feasibility Study* (1980) in the Fessenden Papers, State Archive of North Carolina, Box 1140.104. The plan includes photos and detailed layouts of the wireless experimenting site. No action was taken on the proposal to reconstruct the tower and other facilities, no doubt because of the nearly $1 million projected cost.

44. "Wireless Words—American System Tested at Roanoke Island," *Boston Globe* (April 27, 1902), p. 2. See also, Pickells.

45. Clark "Radioana" Archive, Box 384, file 1. The eye-witness report, which lacks an identified author, cites use of Fessenden's liquid barretter in this test.

46. See, for just one example, "Two Phone System Has Friends and Enemies," *Boston Herald* (December 24, 1906), p. 1.

47. Canadian radio engineer and researcher John Belrose who has extensively studied Fessenden's whole wireless career and accomplishments reports that a late 1906 U.S. Navy listing of ships with wireless equipment shows just two United Fruit vessels, both of which used de Forest devices that were closely copied from Fessenden designs. Three navy ships used Fessenden receivers and three others de Forest devices. Another 36 merchant ships were also using de Forest receivers.

48. Here Fessenden's memory failed him–he had invited Kennelly but the latter could not attend the December 21, 1906 demonstration, and was thus not present.

49. Clark "Radioana" Collection, Smithsonian Archives, Letter of January 29th, 1932, Reginald A. Fessenden to S.M. Kintner, CWC 135-246A. The typescript is labeled at the top as a "COPY." The next and concluding three paragraphs of this letter are quoted in Helen Fessenden's 1940 biography of her husband and form the basis for most subsequent accounts.

50. Reginald A. Fessenden, "Position of the National Electric Signaling Company, January 1, 1907," merely notes on p. 8 of the typescript that "We are of course pushing ahead with the further development of the [wireless] telephone and other work." Fessenden Papers, State Archive of North Carolina, Box 1140.9, file 1.

51. We found plenty of contemporary evidence of this friction. Indeed, in a latter from one of the Pittsburgh financiers written December 27, 1906 (only three days after the supposed Christmas Eve broadcast), Hay Walker complained in a letter to Fessenden that "We are in despair of ever having you keep your promises

and confine yourself to your particular end of the business, in which you have had our loyal support." Fessenden Papers, State Archive of North Carolina, Box 1140.6, file 3. Given the tone of that plaint, it would make sense for Fessenden not to report what might have appeared in the circumstances as a mere stunt.

52. Fessenden, "The First Trans-Atlantic Telephone Transmission," op cit.

53. See, for example, S. M. Kintner to George H. Clark, September 8, 1932 (Clark Radioana Collection, Smithsonian Institution, File 55), a one-paragraph letter written several months after Fessenden's death, when Kinter notes that Fessenden's work had by then "taken such form as to merit such record [a proposed biography], although at the time the work was done I must confess I, for one, didn't attach any such importance to it."

This article was peer-reviewed.

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Fessenden

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AWA Review

Morse Code Training Devices

David and Julia Bart ©2006

ABSTRACT

The telegraph was the primary communication device of the 19th Century and continued to play an important role throughout the 20th Century. As concepts for teaching Morse code evolved throughout this period, entrepreneurs and manufacturers incorporated new technologies and offered an increasing variety of training instruments. This article presents a review of American teaching devices used for Morse code training after 1850. The devices discussed include: training keys, disk and drum devices, paper tape machines, audio visual trainers, oscillators, and phonograph and tape recordings. For over 150 years, these devices provided the means to teach and practice Morse code. They offered a way to replicate the code and provided variation in code speeds and timing for individual and group practice. Use of these devices enabled thousands of telegraphers and wireless operators to work towards achieving greater proficiency levels and standards of performance.

The following article is based on an ongoing research project offering the first comprehensive survey of the devices used, methods employed and the places where American telegraphers received their initial training and instruction in Morse code after 1850. This article presents a condensed summary of the opening section of an upcoming book on these subjects. A review of educational toys as well as a survey of the commercial, military and amateur training programs and the primary teaching methods used for first time instruction in Morse code will be published separately. Training on more advanced devices to accelerate transmission and reception speeds, such as the use of "bugs", "iambic keys" or "paddles", and the application of automatic transmission methods, such as the use of teletype machines, lie outside of the intended scope of this project.

TRAINING KEYS

American telegraphers have always emphasized fast, accurate and reliable transmission and receipt of Morse code and demand for skilled operators grew rapidly from the outset.[1] By the 1860s, entrepreneurs and manufacturers recognized an enormous market opportunity and designed training sets to help telegraphers learn uniform and standardized applications of the Morse code. Thereafter, new innovations brought increasing variation in these training keys and eventually spawned the development of ever more creative training devices.

Learner Sets. The earliest code training keys were used by both commercial and

private line telegraphers. The first of these sets may date from 1849 and included a complete telegraph key and a separate sounder mounted onto a single board to allow for greater portability (Reid, 1879). By the mid-1850s, small pocket sets incorporating a key and relay mechanism came into use as linemen's test sets.

Soon after the Civil War, manufacturers introduced a new class of instruments specifically targeting aspiring telegraphers. Initially termed "Learner Sets," "Learners Outfits," or "Learners Apparatus", these devices consisted of an inexpensive key and a sounder mounted on the same base. Today, many of these sets are referred to more generally as key-on-board sets, or KOBs.[2]

By the mid-1860s, manufacturers began targeting the private line telegraph market and the number of styles and types of Learner Sets and other KOBs began to increase (Prescott, 1866; Casale, 2006; see Figs. 1, 2).

Student manuals of the period stated that these sets could be used by the individual telegrapher or could be wired together for use by two or more telegraphers at distances from 100 feet to 15 miles. Detailed instructions explained batteries, wiring and practice methods for learning the Morse code, including the best approaches for holding the telegraph key and the best methods for writing script to transcribe incoming messages.

As Learners Sets, private line sets and other KOBs achieved greater acceptance, manufacturers varied their styles, materials, intended durability and artistic design to meet the needs of their customers. A wide variety of KOBs were designed for use at home, in business circuits, or in commercial telegraph offices. The primary differences can be seen in the changing telegraph key designs, sounder designs, and the location of the key, sounder and binding posts on the base. In very general terms, major design changes of the telegraph key lever help to date KOBs as follows: Straight Levers

Fig. 2. KOB design: Western Electric Co. Steiner set circa 1886.

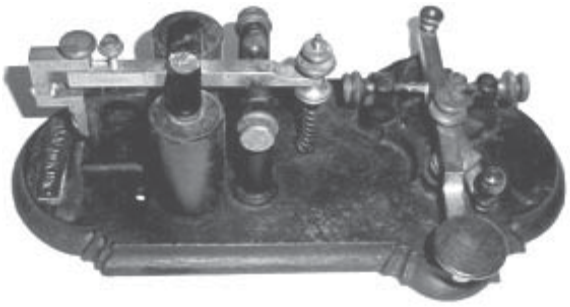


Fig. 1. Private Line Set: Patrick and Carter circa 1870.

(1844-1881), Camelback Levers (1850-1881), Step Levers (1850-1881) and Curved Steel Levers (after 1881) (Moreau, 1995; Perera, 1999).

All of these styles remained in use during the late 19th Century since operators generally owned their telegraph equipment. But by the turn of the century, the Curved Steel Levers proved to be the best design and remained the generally accepted standard. Major manufacturers of KOBs included Tillotson & Co., E.S. Greeley & Co., Partrick & Carter, Foote Pierson & Co., New Haven Clock Co., and Western Electric Company. J.H. Bunnell & Co. was the leading manufacturer of steel lever keys and produced its own highly successful line of KOBs.[3] J.H. Bunnell also produced "Giant" combination KOBs used for training as well as commercial applications. Retail stores and mail order catalogue companies sold KOBs using both the manufacturer's name and the retailer's private label. Major catalogue houses such as Sears Roebuck and Company, Montgomery Ward and other mail order merchandisers offered KOBs along with technical books and other telegraphy products (see Figs. 3, 4).

The Unique
COMBINATION GIANT KEY AND SOUNDER

THE above cut represents the cheapest, simplest and neatest combination set ever put on the market. Both Key and Sounder mounted on an ordinary Sounder Base. Manufactured of handsomely finished bronze Telegraph Metal, Rubber-covered Coils, Nickel-plated Lever Key, and mounted on handsome Mahogany Base. This is a most useful Learner's Instrument, and can be used in any telegraph office in place of the Giant Sounder and Steel Lever Key now used. Takes up less room and requires less adjustment, and will work on one cell of battery. Can be used singly, to learn sounds, or in pairs to connect buildings, etc.

PRICE LIST.

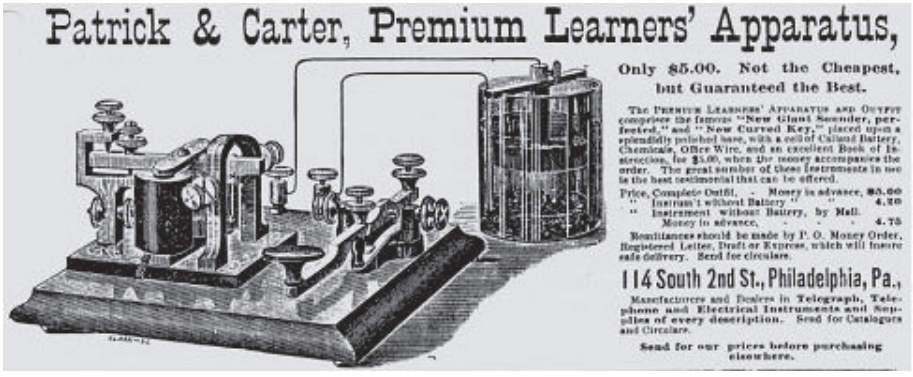
With Local Magnets, for Learner's use ..... $5.00 each.
" 20 Ohm " ..... 6.00 "
Crow-foot Battery, 5×7 ..... 85 "
" " 6×8 ..... 1.35 "
Learner's Outfit, consisting of Unique Key and Sounder, with Battery, Chemicals, Wire and Printed Instructions, packed in a neat wooden box with slide cover ..... 6.00 "

Sent to any address on receipt of price.

JOHN STARR,
DEALER IN
GENERAL ELECTRICAL APPARATUS AND SUPPLIES,
2, 4 and 6 Duke Street, Halifax, N. S.
P. O. Box 101. Illustrated Catalogue on application.

Fig. 4. Learner set leaflet for The Unique Combination Gian Key and Sounder set circa 1895.

By the First World War, the new wireless supply companies such as Electro-Importing Company of New York and Manhattan Electric Supply of-


Patrick & Carter, Premium Learners' Apparatus,

Only $5.00. Not the Cheapest, but Guaranteed the Best.

The PREMIUM LEARNERS' APPARATUS AND OUTFIT comprises the famous "New Giant Sounder, perfected," and "New Curved Key," placed upon a splendidly polished base, with a cell of Callaud Battery, Chemicals, Office Wire, and an excellent Book of Instruction, for $5.00, when the money accompanies the order. The great number of these Instruments in use is the best testimonial that can be offered.

Price, Complete Outfit, - Money in advance, $5.00
" Instrum't without Battery " " 4.20
" Instrument without Battery, by Mail. Money in advance, " " 4.75

Remittances should be made by P. O. Money Order, Registered Letter, Draft or Express, which will insure safe delivery. Send for circulars.

114 South 2nd St., Philadelphia, Pa.,

Manufacturers and Dealers in Telegraph, Telephone and Electrical Instruments and Supplies of every description. Send for Catalogues and Circulars.

Send for our prices before purchasing elsewhere.

Fig. 3. Learner set advertising by Patrick and Carter, *The Electrician*, January 1883.

fered complete telegraph training outfits with new instruction cards and directions explaining how KOBs could be adapted for wireless training.

Multiple makes and models appeared for each manufacturer. For example, in 1912, Manhattan Electric Supply offered its Student Telegraph Set, Eureka Telegraph Set, Learner's Excelsior Telegraph Set and the Wireless Practice Set (*MESCO No. 28*, 1912). Yet, of all the makes and models, J.H. Bunnell's inexpensive and durable sets dominated the industry from the 1880s into the 1920s.

Mechanical Sets. The first cable operated mechanical training devices date as early as 1870. D.W. Putt and Company and other manufacturers produced devices where the movements of the key mechanically pulled the sounder via a cable or wire that ran under the KOB platform. These training keys did not use electricity and relatively few of these sets were manufactured.

Between 1885 and 1890, the Anderson Guinan Mfg. Company of Cleveland, Ohio offered "The Telegrapher," a cast-iron non-electrical set employing a metal rod to operate the sounder from movements of the key.

Manhattan Electric Supply's *MESCO Catalogue Number 18* offered two late variations applying a connecting cable or rod between the key and sounder. The Eureka Combination Electric and the Improved Giant Combination Electric each featured a KOB design with a separate key and sounder that came with an attachment for directly connecting the sounder's armature to the key, permitting mechanical practice without a power source. The main difference between these two MESCO sets arose from the location of the key on the base and the size of the sounder (see Figs. 5-7).

The J.H. Bunnell Company Catalogue for 1895 featured two J.H. Bunnell Mechanical Sets that physically joined the moving elements of the key and sounder into a single frame. Bunnell's Mechanical Set No. 1 allowed the operator to tap the sounder's armature directly up and down with a finger knob mounted to the side of the armature. Bunnell's Mechanical Set No. 2 separated the knob from the sounder's armature with a

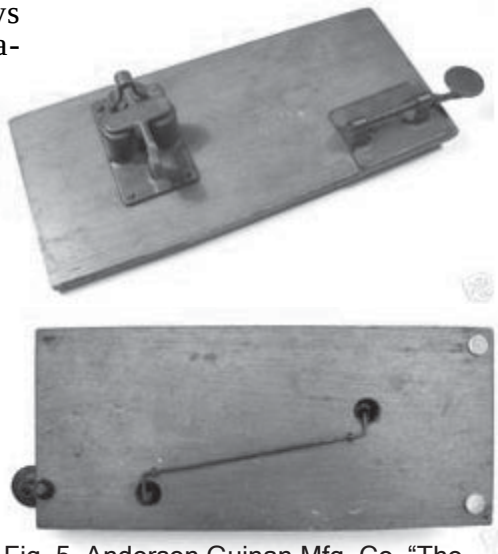


Fig. 5. Anderson Guinan Mfg. Co. "The Telegrapher" cable operated KOB circa 1890.

Fig. 6. One Piece Mechanical KOB: J.H. Bunnell No. 1 circa 1895.

Fig. 7. One Piece Mechanical KOB: J.H. Bunnell No. 2 circa 1895.

spring, thereby permitting the telegraph key's tension to be independently adjusted while also changing the sounder's acoustics to more closely resemble an actual operating sounder.

In 1900, Manhattan Electric Supply Company adapted Bunnell's designs with its own MESCO Training Key also known as the Mechanical Telegraph Instrument (*MESCO No. 28*, 1912; *The Telegraph Office*, 2005). The MESCO key used wooden spools in the shape of a sounder's electromagnetic coils. (*The Telegraph Office*, 2005) Depressing the key directly pulled down the steel contact bar onto the spools, creating the sound and feel of live Morse code. A 1915 catalogue from Central Electric Company offered the Ludwig Mechanical Telegraph Instrument following a similar concept.

Buzzer Sets. After Guglielmo Marconi's 1895 radio demonstrations, the emergence of wireless telegraphy led to even greater marketing and application of the original KOB designs to a new audience. By World War I, manufacturers began substituting a buzzer for the more traditional sounder in wireless training sets. Gernsback's Wireless Course first advertised its new buzzer KOB in 1914, targeting the growing market for amateur radio enthusiasts. Gernsback's 1918 wireless training device, the Electro-Codaphone, featured an adjustable buzzer located above the key which provided "*the only instrument made that will imitate a 500*

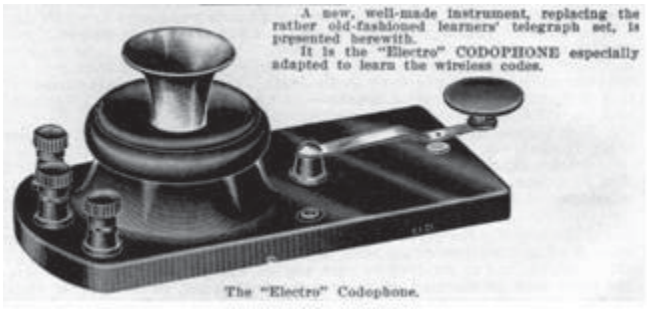

A new, well-made instrument, replacing the rather old-fashioned learners' telegraph set, is presented herewith.
It is the "Electro" CODOPHONE especially adapted to learn the wireless codes.
The "Electro" Codophone.

Fig. 8. The Codaphone buzzer set by Gernsback, 1918.

Fig. 9. Combination buzzer and blinker set: Frank B. Perry and Sons Radio Blinker Signal Set dated September 4, 1917.

cycle note exactly as heard in a wireless receiver, so closely and wonderfully clear, that radio operators gasp in astonishment when they first hear it" (Gernsback, 1918).

The set could be adjusted to sound like an army training buzzer or an individual practice set. It could also provide the volume necessary for classroom demonstration. Multiple students could use this set for practice by linking two or more sets together on a common circuit. Other buzzer sets included the 1917 Frank Perry and Sons Radio Buzzer Blinker Signal Set and the 1921 Ajax Electric Company Learner's Key and Buzzer Set (see Figs. 8, 9).

Late Model Trainers and Toys. In the 1920s, traditional KOBs with a key and sounder continued to be produced for both commercial and private line telegraphers. New wireless training keys also included a light for blinker or visual training. The most prominent manufacturers of the 1920s who provided traditional KOBs, buzzers and lights for wireless training included Manhattan Electric Supply Company, J.H. Bunnell Company, Electro-Importing Company of New York and Electrical Supply Company. Newly developed plastic technologies eventually brought many lightweight variations to these devices, replacing many components with bakelite or other forms of molded plastics. These less expensive sets include Les Logan's Speed X line and keys manufactured by E.F. Johnson, William M. Nye Company, Philmore and M.M. Fleron (see Fig. 10).

After the First World War, the market for toys exploded and many manufacturers capitalized on the public's fascination with radio by providing toy telegraph sets to learn Morse code. Many toy sets combined both buzzer and light training. They targeted the growing amateur markets as well as offering novelties for children. Although these toys achieved popularity, they never gained acceptance as serious tools for learning code. Yet, toy sets included a number of

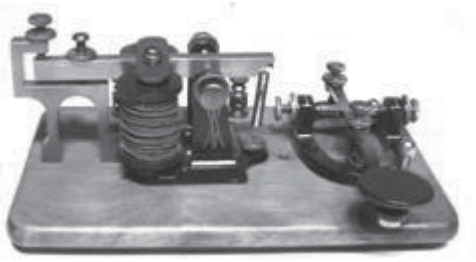


Fig. 10. Manhattan Electric Supply Company (MESCO) amateur KOB circa 1920.

buzzer, light, sounder, and even oscillator innovations, and they were widely used. Many amateur radio enthusiasts recall receiving their first exposure to Morse code on toy sets.

As the 19th Century closed, the primary means of practicing code for new telegraphers was the basic key and sounder of the original Learner Sets, or KOBs. Their continued use well into the 20th Century demonstrated their enduring and practical design. But, these simple sets offered no means to consistently control the student's rate and timing of the individual dots and dashes. A more sophisticated approach was needed to instill greater uniformity among both telegraphers and wireless operators, who increasingly expected consistent performance and reliable proficiency with Morse code as common industry practice.

DISKS AND DRUMS

By the turn of the century, new training devices employed standardized methods of controlling the key-to-sounder circuit, thus regulating the timing of the student's code transmission. These devices used notched disks or pre-cut drums and a moving stylus to trigger the current in the circuit. By providing pre-made disks and drums that specified timing for the dots, dashes and spaces, budding telegraphers could learn and practice Morse code to achieve the expected standards of acceptable performance.

Omnigraphs. The Omnigraph Manufacturing Company of New York was established in 1900 and made its first sales of a new training device, the Omnigraph, through a J.H. Bunnell Co. catalogue that same year (Pennes, 2002 and 2006). Omnigraph promised to teach both the wireless and Morse codes "in half the usual time" and the Omnigraph came to be used extensively by the government, universities, colleges and trade schools (Omnigraph, 1918).

The *Sears Catalogue* offered the earliest versions of the Omnigraph beginning in 1902 (Sears, 1902). The Sears single-disk model included a hand cranked single aluminum disk with a key and sounder mounted as a KOB on a mahogany base. The disk read "JOHN QUICKLY EXTEMPORIZED FIVE TOW BAGS." An optional battery-powered motor and pulley system were also available to rotate the disk making the Omnigraph the first fully automatic training device. It generated code from the movement of an electrical contact that tracked along the raised edge of a flat aluminum disk. As the disk rotated, notches on the rim opened and closed the electrical contact enabling a sounder, buzzer, or headphones to operate. Early Omnigraphs came with the instructional booklet, *How to Become an Excellent Operator*. Extra disks for this first Omnigraph were available at five cents each (Pennes, 2002 and 2006).

The Omnigraph Company primarily focused its advertising in land line telegraph journals until about 1910 when it began selling its products as wireless training devices. By World War I, the company succeeded in its efforts to have the Omnigraph become the first device used for testing national proficiency standards in transmitting and receiving Morse code (Friedman, 1984). Both the 1914 and 1919 rule-books of the new U.S. Department of Commerce's Radio Service stated that each amateur and commercial operator license code test be "conducted by means of the Omnigraph or other automatic instrument" (Omnigraph, 1918). As the U.S. entered World War I, the U.S. military purchased large numbers of Omnigraphs to train both its telegraph and wireless operators (Friedman, 1984; Pierpont, 2002; see Figs. 11-13).

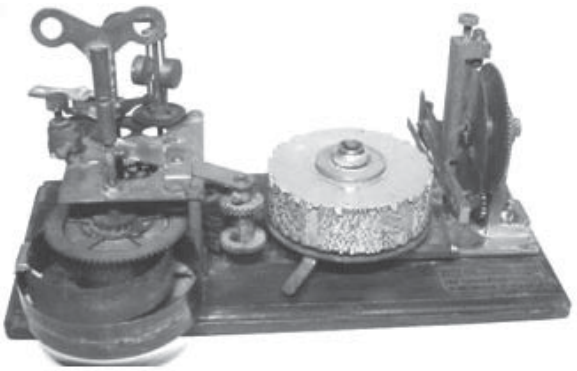


Fig. 12. Omnigraph No. 2 circa 1909, 15-disc model.

As demand grew, Omnigraph produced different models that provided up to 60 practice disks. By 1917, the Electro-Importing Co. of New York advertised Omnigraphs for amateur wireless code training featuring a five disk "junior" model and the larger 15 disk model. J. H. Bunnell, Manhattan Electric Supply Company and Radio Service Company also sold Omnigraphs (Pennes, 2002 and 2006).

By 1922, a larger 5 disk practice set complete with a key and buzzer became available. These larger versions employed a spring driven clockwork mechanism to automatically push the contact arm up and then down the stack of disks. Speeds from 5 to 100 words per minute could be achieved by adjusting the motor's governor (Omnigraph, 1918; Friedman, 1984; Pennes, 2002 and 2006). Omnigraph company advertisements stated that the Omnigraph could "send unlimited messages by the hour at any speed". The company claimed the Omnigraph could

Fig. 11. Omnigraph Mechanical Disk Learner's Set No. ! circa 1902.

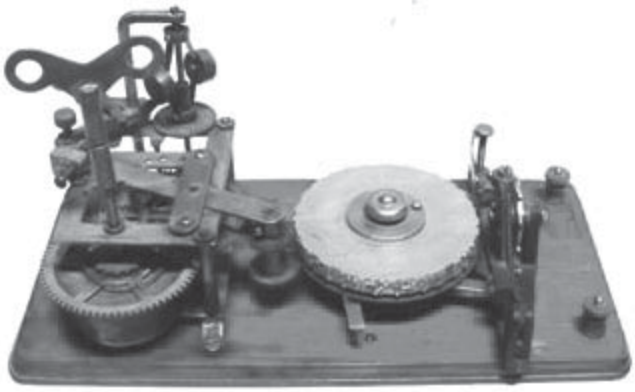


Fig. 13. Omnigraph 5-disk No. 2 "Junior" model circa 1924.

run for 45 minutes with a single winding of the clockwork motor. (Omnigraph, 1918) Practical experience showed that the sets actually began to slow down after 20 to 30 minutes of use (Friedman, 1984; Pennes, 2006). Changing the order of the disks and the speeds provided variation for practice while always maintaining the uniform timing of the individual dots and dashes. Each disk contained from 12 to 36 characters and disks were available in both American Morse and Continental code. Additional disks could be purchased in groups of five for $1.00. Available disks included the alphabet, single letter disks, numerals, punctuation, railroad, commercial, press systems and interchangeable messages (Omnigraph, 1918; Friedman, 1984; Pennes, 2002 and 2006).

During their heyday, Omnigraphs heavily advertised in the major telegraph, wireless and radio journals of the period including *QST*, *Radio Amateur News, Radio News, Electrical Experimenter, The Wireless Age, Western Union Tariff Circular, Journal of The Telegraph,* and *Radio.* Many classroom correspondence schools also advertised Omnigraphs and sometimes distributed them to students under proprietary trade names. The National Wireless Institute and the New York Wireless Institute sold or used Omnigraphs in their training programs under private labels, putting their name on the instrument (Pennes, 2006). International sales were made through A.W. Gamages, Ltd. in London under the Gamages label. Omnigraph advertisements appeared as late as 1927 and the company ceased operations in 1931. During its lifetime, the Omnigraph Company produced at least 15 models of the Omnigraph training device (Pennes, 2002 and 2006).

Homemade Devices. During World War I, amateur radio operators were prohibited from broadcasting due to national security concerns and the emerging monopoly placed on radio by the U.S. Government. Effective April 17, 1917 through October 1, 1919, the government ordered all amateur equipment dismantled and prohibited amateurs from receiving and transmitting radio signals (DeSoto, 1936; Pierpont, 2002). Though prohibited from radio

operations, amateurs who did not join the military were encouraged to make their own practice devices to maintain their code skills.

One popular device included an award-winning homemade paper disk trainer featured in the September, 1918 issue of *Wireless Age*. Strips of tin foil pasted to cardboard disks were connected to a copper wire and a motor. The tin foil was cut by the user into code patterns for practice (*Apparatus For Self Instruction*, 1918). The need for homemade devices waned after the war when amateur operating rights were restored.

Natrometers. First advertised in 1920, the National Radio Institute (NRI) in Washington, D.C. exclusively manufactured a new device called the Natrometer for teaching Morse code to both private line and commercial operators. The Natrometer succeeded the Omnigraph with its new technology, but NRI only featured it for only a few years in its courses.

Advertised as "the most efficient instrument ever devised for teaching wireless code", the Natrometer allowed both random code generation and speed adjustment (*Practical Radio*, 1927). A clock-work movement controlled the mechanism. The circuit operated with an aluminum drum that had 9 levels of insulated (blackened) and un-insulated (exposed) patterns painted on the sides. As the drum rotated, the patterned sections passed under copper contacts, opening and closing the circuit to operate a sounder, buzzer or headphones. Contacts could be selected by inserting or removing wooden pins. Like the Omnigraph, overall speed was adjusted using a brake on the motor's governor while the spacing between the individual dots and dashes remained uniform. Additional drums with different patterns of letters and numbers were also available for purchase and several models featured a key and buzzer (see Fig. 14).

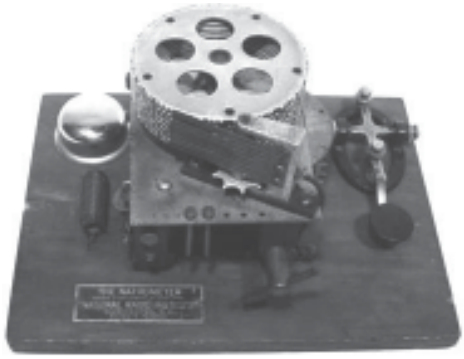


Fig. 14. Natrometer as sold by the National Radio Institute circa 1926.

NRI featured the Natrometer in its 1927 guide *Practical Radio: Be A Radio Expert* and offered the Natrometer as a supplement to its radio courses for more specialized Morse code training. It provided the Natrometer, headphones and a learner's KOB at no cost to students claiming "*...the Natrometer gives you code-speed in half the usual time... [and] will send messages in a human and not a mechanical manner at a rate which you can vary from 3 to*

30 words per minute...The effect of static interference may be added to the messages being copied...." (*Practical Radio*, 1927) Natrometers were not separately advertised for sale outside of the NRI courses and were never used in official testing.

Other Devices. In 1940 an unusual device combined the features of both the Omnigraph and Natrometer. Of unknown manufacture, the Santa Fe Railroad used this device to train its operators. It incorporated the code onto a pattern of elevated surfaces on the side of a large aluminum drum. Nothing more is known about this device (*The Telegraph Office*, 2005).

The June, 1960 *QST* featured advertising from the Teleplex Co. offering its own copper engraved code drum device to teach the code by sound. Teleplex's "Automatic Transmitter" had seven lessons available and Teleplex claimed to teach individual letters in "seconds". *QST* and *CQ Magazine* both advertised the Parks Code Wheel from Park Electronics Laboratories in 1963 (*QST*, May, 1963; *CQ*, May, 1963). The Parks Code Wheel offered an "exceedingly rugged" motorized disk machine with Morse code characters cut into the edge of the disk much like the Omnigraph. The advertisements proclaimed it as self-contained and ideal for contests (*QST*, May, 1963; *CQ*, May, 1963).

As late as 1970, another hand cranked disk device, the

CODE
TELEPLEX METHOD
trains you to hear Code signals just as you hear spoken words — because it teaches Code SOUNDS and not dots and dashes. Thirty words with ease...fifty words not unreasonable! Start beginner or advances your present speed. Try it for yourself and compare with anything else. 40 years' experience teaching Code have made the Teleplex Method far superior to all the cheap "gimmicks" on the market. Write today for details and free trial. You be the Judge! (Improved cabinet design allows new low cost.)
TELEPLEX CO.
739-D Kazmir Court, Modesto, Calif.
Canadian Representative: THE HAM SHACK
1269 Granville St., Vancouver, B.C.

Fig. 15. Teleplex ad from *QST* August 1960.

Co-Tutor, was advertised by Romney Engineering Laboratories. Essentially a hand held whistle, sounds were made by blowing into the device while simultaneously turning a crank to rotate one of six snap-on code disks. The Co-Tutor came with American Radio Relay League's book *Learning the Radio Telegraph Code*. (*QST*, October, 1970; see Fig. 15)

Of all the disk and drum teaching devices, the Omnigraph's simple mechanism was easier to operate, more durable and less fickle than the Natrometer. The U.S. government's early selection of the Omnigraph for radio operator testing by 1914 helped ensure its commercial success. Consequently, the Omnigraph became the preferred disk/drum wireless training device throughout the 1920s. As a result, Natrometers and the other cylinder type devices never achieved wide acceptance, and Omnigraphs dominated the early trade schools and training programs. But even the Omnigraph had its limitations, and by the 1930s, the

Omnigraph was being replaced by more efficient and effective paper tape devices (*The Telegraph Office*, 2005).

PAPER TAPE DEVICES

Paper tape training devices date as early as 1901. By the 1930s, these devices dominated the market, offering simplified mechanical designs that provided greater variation in recorded training sessions at significantly lower cost. These devices maintained a strong presence in the market for training sets well into the 1960s.

Audible Alphabet Transmitter. The Audible Alphabet Transmitter was the first training device to use paper tapes with perforated holes to operate a sounding mechanism. C.S. Cumins patented the transmitter in 1901 intending it for private study and practice. The Audible Alphabet Company of Boston manufactured it, and Theo A. Edison's 1902 book *Telegraphy Self Taught* featured its use (Edison, 1902). The A.A. Transmitter pulled a perforated paper tape through the instrument with a hand-cranked mechanism. The holes in the paper permitted an electrical signal to be transmitted as each hole moved over an exposed electrical contact. The rate of manual turns controlled the speed. A battery and sounder completed the circuit. Edison postulated: "It is not the speed at which the letter is sounded that perplexes the learner, but the rapid succession in which they [the letters] follow each other" (Edison, 1902).

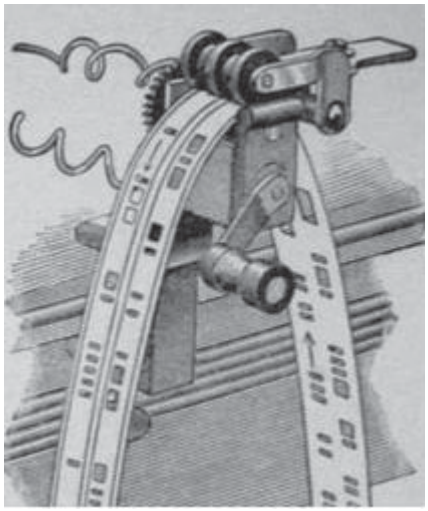


Fig. 16. Audible Alphabet Automatic Transmitter, Edison, 1902.

The paper tapes provided uniformity in the spacing between the transmitted letters regardless of the speed at which the tape was played. Beginner tapes used wider spacing between the letters. More advanced tapes used shorter spacing between the letters. Through practice, the student would progress to ever shorter intervals until attaining "normal telegraph spacing" and an expected proficiency of 25 words per minute in five letter character groups. The device came with six perforated paper tapes and an instructional booklet (Edison, 1902). The Audible Alphabet may have been available as late as 1920 (Smith, 1997; *The Telegraph Office*, 2005; see Fig. 16).

Automatic Telegraph Transmitter. The National

Automatic Transmitter Company produced its own "auto-alphabet instrument", the Automatic Telegraph Transmitter, based on a concept originated by R.W. Elam of Valparaiso, Indiana.[4] First offered in a 1900 J.H. Bunnell Catalogue, this device included a key, sounder and batteries together with a clockwork mechanism that automatically pulled a strip of perforated paper across the electrical contacts to activate the sounder. Manipulation of the governor on the clockwork mechanism controlled the speed similar to the operation of the Omnigraph. Speeds could range from five to forty words per minute and each tape could hold from 300-500 words. The entire series of tapes offered 10,000 words. The key could also independently operate the sounder. (J.H. Bunnell, 1900) *An Electric Telegraph Course* accompanied the Automatic Transmitter. Students of the American School of Correspondence received both the transmitter and instructional course materials ("The Electric Telegraph", 1909; see Fig. 17).

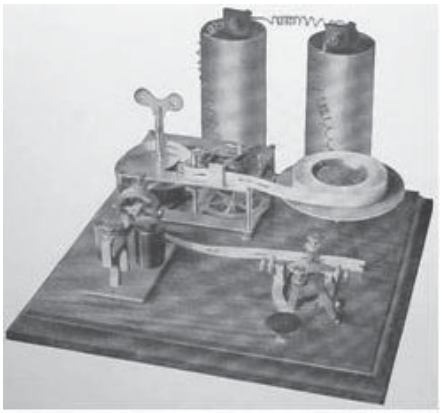


Fig. 17. Automatic Telegraph Transmitter produced by the National Automatic Transmitter Company, 1909.

The transmitter's paper strips followed the six advertised course programs including groups of letters, numbers and words. The transmitter and course materials were provided to students for a deposit which was refunded when the instrument was returned in good condition ("The Electric Telegraph", 1909). The Automatic Transmitter was also available through Manhattan Electric Supply Company Catalogues and Dodge's Telegraph and Railway Institute where it came with the book *The Telegraph Instructor* (*MESCO No. 18*; *Telegraphy Successfully Learned*, 1912).

Teleplex. By 1927, the Teleplex Corporation marketed a new training device to commercial, private and military audiences that used rolls of punched double-sided wax paper tape to generate hundreds of code patterns for sounder, buzzer or headphone operation (*QST*, April, 1927). Initially sold with a spring driven motor, later models used an electric motor to drive the tape winding mechanism. In both models, a lengthy single paper tape provided more code practice than dozens of Omnigraph disks or Natrometer drums at far less cost, and the offerings greatly exceeded those available from the Automatic Telegraph Transmitter (Friedman, 1984; Pierpont, 2002).

THE
Perfectograph
WITH THE PERFECTOGRAPH you can easily become a Broker, Press or Expert Relay Operator—right in your own office, and without embarrassment or hard knocks. The Perfectograph reproduces actual sending of EXPERT operators—5 to 50 words a minute. It sends you quotations, market reports, gossip, executes orders the way it is done in broker offices. It sends you 'Philips' code as it is sent over fast Press wires. It sends you routine business handled in large relay offices. It will POSITIVELY make you proficient in any branch of telegraphy in a short time. A recent purchaser writes that The Perfectograph has already improved his ability 100 per cent and increased his salary 33⅓. YOU can do as well or better.
Members of G. R. T., write for particulars about beginners' course in Morse Telegraphy.
PERFECTOGRAPH COMPANY
New York, N. Y.

Fig. 18. The Perfectograph (*The Railroad Telegrapher,* September 1927).

By 1932, Teleplex advertised an all electric Master Teleplex code Teaching Machine that came with an instruction book and either a telegraph

Fig. 20. Instructograph advertising (*QST*, March 1930).

It Teaches the Code!
WARNING!
A Personal Message to Every Fair-Minded Reader of QST
from R. G. MILLER, Inventor of Teleplex, the original code instructor Manager, Teleplex Company
Learn Telegraphy with TELEPLEX
TELEPLEX TEACHES YOU THE CODE
FREE 10 DAYS' TRIAL
TELEPLEX COMPANY
DON'T BE MISLED BY IMITATIONS. TELEPLEX IS THE GENUINE CODE INSTRUCTOR.

Fig. 19. Teleplex advertising (*QST*, April 1930).

key or right angle "bug" for high speed practice. The Master Teleplex could record and replay the student's code transmission, enabling the student to study errors and practice receiving the student's own messages. (*Radio News*, December, 1932)

By 1940, the Improved Master Teleplex was equipped with copper tapes on which the code was embossed for error-free operation (*QST*, March, 1935). Teleplex later offered

MASTER THE CODE
WITH MASTER TELEPLEX
THIS TAPE was made on MASTER TELEPLEX by "Bug" sending
YOU CAN'T GO WRONG WHEN YOU CAN SEE WHAT YOU ARE DOING!
ALL ELECTRICALLY OPERATED
Just plug it in
THERE IS ONLY ONE WAY TO LEARN TO RECEIVE THE CODE SIGNALS AND THAT IS BY LISTENING TO THE SIGNALS. THERE IS ONLY ONE WAY TO LEARN TO SEND THE SIGNALS PROPERLY AND THAT IS BY BEING ABLE TO SEE AND HEAR YOUR OWN SIGNALS.
WITH MASTER TELEPLEX YOU LEARN THE CODE IN THE NATURAL, EASY, FASCINATING WAY. THERE IS NO GUESSWORK BECAUSE YOU ACTUALLY SEE AND HEAR WHAT YOU ARE DOING!
Learning to send PROPERLY is more difficult than learning to receive. Most people think sending is easy. Well, just ask the fellow who tries to receive it!
How do you make the letter "C"? Of course not like the third one shown below. But you might be surprised! Actually, most professional operators are astounded to see their sending recorded on MASTER TELEPLEX.
MASTER TELEPLEX will show you exactly how you make the letter "C" and all the rest of the characters. And it will show you how to make them correctly!
CATALOGUE OR EXPLAINS FULLY THE MANY INTERESTING AND FASCINATING FEATURES OF MASTER TELEPLEX. It also lists above other types of Code Teachers. Just send a post card asking for catalogue Q8. No obligation.
TELEPLEX CO.
67-69 Park Place New York City
In Canada Write CANADIAN ELECTRONIC INST., TORONTO, ONT.

Fig. 21. Improved Master Teleplex Code Training Machine, (*ARRL*, 1940).

similar models. Improved calibration of speeds, elimination of the mechanical disk changer, greater variety and extended duration of the paper tapes all contributed to the success of the paper tape instruction machines over the disk and drum machines. Advertisements for the Teleplex paper tape machines appear through 1965 (N7CFO, October 30, 1992; see Figs. 18-21).

Perfectograph and Instruct-O-Graph. The success of the Teleplex spawned numerous competitors. The Perfectograph Company of New York advertised its competing machine in 1927. Their *Beginner's Course in Telegraphy* used a hand cranked paper tape machine similar to the original Teleplex. The Perfectograph's paper tapes permitted practice speeds ranging from 5-80 words per minute. (*The Railroad Telegrapher*, September, 1927).

Beginning in 1930, the Instruct-O-Graph Company of Chicago offered a similar instrument that used a thin single paper tape which provided even more code practice at still lower cost (*QST*, March, 1930; N7CFO, October 30, 1992). Instruct-O-Graph offered both the Standard and Junior models using either an electric motor drive or a spring drive to wind the punched paper tapes onto collecting spools (*Practical Radio*, 1927). The Instruct-O-Graph was designed for use with KOBs, free standing sounders, buzzers and headphones. (Kirkpatrick, 1947) Perforated paper tape rolls and an instruction booklet by O.B. Kirkpatrick provided the training program. Speeds ranged from 3-40 words per minute. As a general rule, students were told when they could copy at 90% accuracy, they could move

on to the next tape. (Instruct-O-Graph, 1947; Kirkpatrick, 1947) The number of words per minute was controlled by the spacing on the tape and not by motor speed to enable the student to receive "clear, concise and correctly made signals, regardless of whether the speed is four or forty words per minute." (Instruct-O-Graph, 1947; Kirkpatrick, 1947)

Tapes were available in both American and International Morse and additional tapes could be purchased. Instruct-O-Graph recommended practice at a pace of one tape per month for part time study or one tape every two weeks for dedicated full time study with multiple separate 15 minute practice sessions suggested. (Kirkpatrick, 1947) Instruct-O-Graph offered to rent its machines for as little at $5 per month with the tapes and instruction booklet. Rentals including an oscillator, headphones and telegraph key cost $6 per month. (Instruct-O-Graph, 1947) Advertising for the Instruct-O-Graph continued as late as 1974 (N7CFO, October 30, 1992; Pierpont, 2002).

National Radio Institute (NRI) courses featured a similar instrument to the Instruct-O-Graph beginning in 1934 called the Nacometer. The Nacometer operated with a spring wound motor and came with instruction manuals and training literature. NRI offered the Nacometer together with a tube driven audio oscillator kit which used parts from NRI's Home Experimental Outfits. (*Rich Rewards*, 1934; N7CFO, July 7, 1994).

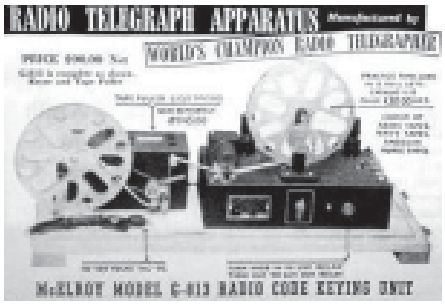


Fig. 22. McElroy Manufacturing Corporation Radio Code Keying Unit (*ARRL*, 1942).

Automatic Keyers. During World War II, new automatic keyers were developed for the U.S. military that soon became available to the general public. These automatic keyers relied on an oscillator tube and keying tube triggered photo-electri-

Fig. 23. McElroy Manufacturing Corporation Code Recording Device (*Radio News,* November 1942).

cally by light variations through a moving inked paper tape. They had sufficient power to operate practice handsets or practice tables for classrooms. Multiple practice tapes were available as well as take-up reels. They could also be used by small groups in the field or could be used as an oscillator for hand keying practice (*War Dept. TM 11-443*, 1943; *War Dept. TM 11-447*, 1943). Many of these devices were commercially produced for the public by McElroy Manufacturing Company and Gardiner-Levering Company (see Figs. 24, 25).

The Army designated these paper tape keyers as TG-10-A or TG-10-B depending on the type of power supplies they used. Demand was low for the TG-10-A type keyer compared to the Gray Manufacturing Company's TG-10-B. The Army introduced a third keyer that combined the automatic paper tape keying system with a tone

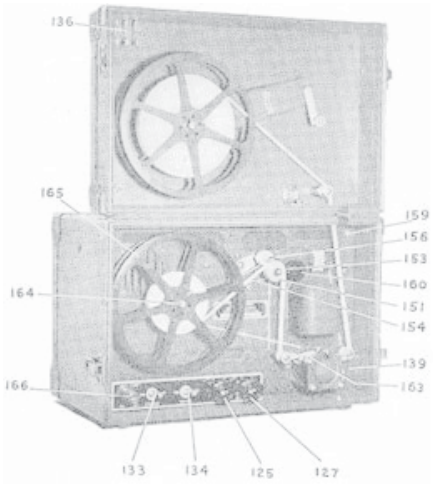


Fig. 24. U.S. Army TG-34-A Code Keyer (*War Dept. TM 11-443*, 1943).

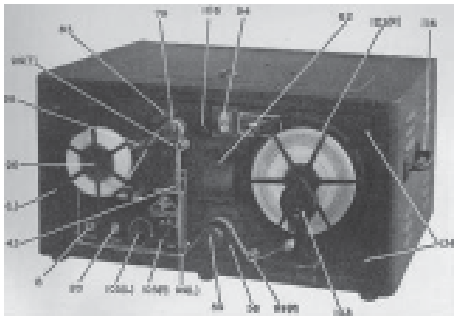


Fig. 25. U.S. Army TG-10-J Code Keyer by Gray Manufacturing Co. (*War Dept, TM 11-447*, 1943).

oscillator in a single unit known as the Lon-Ga-Tone Automatic Keyer. McElroy and Company produced its own Recorded Model RRD-900-742 for the Army as well as its civilian counterparts that could record and playback student transmissions at speeds up to 20 word per minute (*War Dept. TM 11-432*, 1942). The fifteen practice tapes provided were based on training tapes furnished by the U.S. Signal Corps (*ARRL*, 1942 and 1962; *War Dept. TM 11-432*, 1942; Smith, 1997). The McElroy machines remained available into the mid-1960s.

McElroy may have had some involvement in developing the all electric Ayers Automatic Code Machine, available from 1941-1943 (*QST*, April 1942; N7CFO, October 30, 1992). These machines could be rented along with recording slip tapes and special tapes using custom inks. The Ayers Code Machines used a photo-electric tube to read the paper tape, similar to the McElroy devices (N7CFO, February 12, 1993; see Figs. 22, 23).

Gardiner-Levering Company, known as Gardiner and Company after 1942, introduced its own paper tape machine, the "Robot Radio Key," in 1936 (*QST*, November 1936; N7CFO, October 30, 1992). The Robot Radio Key had a loop for the perforated paper tape that allowed messages to repeat indefinitely. By 1940, Gardiner offered the Type J and Type S models. The Type J model included a built-in code perforator together with the automatic sender. Gardiner claimed the Type S model was the most compact code teaching machine available (*QST*, November 1940; N7CFO, October 30, 1992). These devices allowed adjustable speeds up to 70 words per minute to record the student's transmissions for play back, and were relatively compact and quiet due to the use of a new "induction motor" (Smith, 1997). Gardiner advertised its machines until 1965 (N7CFO, October 30, 1992; Smith, 1997). Both the McElroy and the Gardiner Automatic Sender came with pre-cut practice tapes as well as blank tapes.

Telegraph Keyer Corp. and other companies made similar competing paper tape machines into the 1960s. Automatic Telegraph Keyer Corporation offered one of the last models in 1964. Model A provided tapes promoting Automatic Telegraph Keyer Corporation's own ATKO Method of learning code. The less expensive Model B did not come with a tone source or speaker (*CQ*, December 1964).

AUDIO VISUAL TRAINERS

With the arrival of 20th Century, training philosophies shifted away from rote memorization and moved toward multi-sensory approaches which led to new products that combined auditory, visual and even tactile learning experiences. Audio-visual trainers mimicked the sound and/or sight of radio-telegraphy signals by offering blinking lights and electronic sound reproduction. Raised pattern, traceable outlines of the Morse code also made possible a multi-sensory training experience for the novice operator by providing visual stimulation, auditory queues and tactile experiences.

Clickers. The simplest devices for auditory training were handheld clickers which produced a sharp sound when the clicker was depressed between the student's fingers. The 1912 *Manhattan Electric Supply Catalogue No. 18* offered the unique Snapper Sounder, a version of the common toy grass-

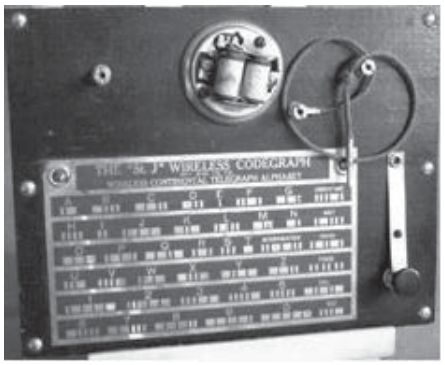


Fig. 26. "St. J." Wireless Codegraph code plate trainer with Continental Alphabet, stamped August 13, 1912.

hopper clicker for audible practice.

Code Plate Trainers. Code Plate Trainers provided an electrically conductive transmitter plate that the student could trace, thereby completing a circuit with a stylus wired to a buzzer, light or oscillator. The plate had metal contacts patterned after the Morse code signals for each letter of the alphabet, numbers and some punctuation symbols. The student could thereby see, feel and hear the patterns of dots and dashes as the raised, or engraved, surface was traced and the student read the pattern and heard the sounds (see Fig. 26).

The first of the Code Plate Trainers appeared in 1910 as advertised by Thomas M. St. John. His new Codegraph provided a plate, stylus, key and sounder, and instruction book. As the stylus, or pen, is "drawn over the plate, the sounder responds and shows exactly how every letter and signal should sound" (St. John, 1910). Insulating material covered the surface of the plate with bare spots corresponding to the dots and dashes of the Morse code including letters, numbers and some punctuation marks.

The Codegraph also came with an optional "Duplex" sounder that incorporated a switch allowing a buzzer to simultaneously operate with the sounder. (St. John, 1910). St. John produced two different "St. J." Wireless Codegraphs in 1912. A stand alone unit featured the Morse Telegraph Code and a combination unit with a simple strap style telegraph key featured the Wireless Continental Telegraph Alphabet. The St. J. Wireless Codegraphs were also sold under the Manhattan Electrical Supply Company "MESCO" name as the MESCO Codegraph together with an optional wireless practice KOB (*MESCO*, 1912).

Other Trainers. Few other Code Plates were produced in the 1930s and 1940s. One unnamed Code Plate in the AWA Electronic Communication Museum's collection likely dates from the mid-1930s. This device shows that a Code Plate could be made by painting the conductive surface of the transmitter bars, providing the necessary insulation to define the dots and dashes. However, the available signal patterns do not correspond to the Morse or other telegraph alphabets, and this device simply offers practice with differing sounds (see Fig. 27).

The 1943 Code-Tutor by International Electric Company offered greater versatility since it came with a buzzer and J-37 style U.S. military telegraph key. The 1958 Easy Code Jr. by

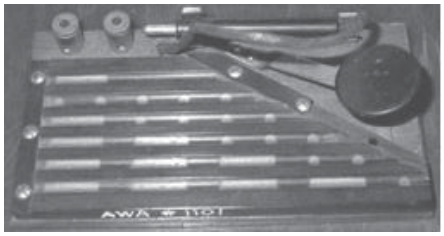


Fig. 27. Unmarked code plate circa mid-1930s.

Aerovox Corporation more closely resembled a toy with its lightweight construction, telegraph stencil pad and hide-away practice key that folded under the main assembly. Finally, in 1970, the Stuhlman Engineering Company offered its Code Board using printed circuit board technology and changing the direction of stylus movements from left/right to up/down (*QST*, April, 1970).

OSCILLATORS

Oscillators also offered a multi-sensory approach for teaching Morse code that sought to reinforce the visual and auditory sensations available for embedding the code into the operator's memory. Manufacturers handbooks stressed that significant code practice would automate the operator's facility with Morse code as a language, and would move the operator away from counting the individual dots and dashes. Generally, code practice oscillators provided either or both audio-tone and visual blinker light reproduction of the signal. Many manufacturers made oscillators and sold them under various brand names. Historically, they fall into four broad groups: (i) tube oscillators driven by radio tubes primarily for sound reproduction; (ii) solid state oscillators relying on transistors and solid state technology for both light and sound reproduction; (iii) combination sets featuring telegraph key and oscillator combinations utilizing either tube or solid state technology; and, (iv) home-made oscillators.

Tube Driven Oscillators. Tube driven oscillators first emerged in the 1940s and 1950s for the amateur ham radio markets. Many varieties of these oscillators became available, but all maintained a simple design and provided similar features. These sets typically came in a metal case and used a one tube circuit which could be connected to a separate telegraph key. The oscillator came with a built-in speaker or could be connected to a separate speaker or headphones. Popular brands included AMECO, BUD, Codemaster, ICA (Insuline Corporation of America), TAC (Telegraph Apparatus Company) and others. Manufacturers sold tube oscillators both as finished products and as kits to be constructed by the user. Key features included adjustable resonators, volume control, tone frequency adjustments, optional headphone connections and separate or built-in telegraph keys.

Solid State Oscillators. Changes in technology led to the conversion of tube driven oscillators into solid state and integrated circuit devices. Less expensive manufacturing in the 1960s combined with the use of integrated circuits to make oscillators smaller and more lightweight. The addition of a light permitted the sender to practice with visual queues as well as audio reinforcement. These oscillators came in both kit form

and as pre-assembled units ready for use with either headphones or external speakers and often came with a separate external telegraph key. Notable examples include the Heathkit line; Knight Code Oscillators for light, speaker and headphones; Electronic Instrument Corporation's EICO line; and AMECO's CW brand for use with headphones or speaker.

Combination Sets. Combination sets either contained their own speakers or utilized radio speakers for sound reproduction. The oscillator typically had its own tube driven audio output circuit providing its own amplification for the radio's speaker, or could rely on the radio's circuits for amplification by simply providing the audio signal for the radio. In both cases, the oscillator came equipped with its own key for closing the circuit. In the 1930s, Bud Radio of Chicago offered a training oscillator featuring a sideswipe key for connection into a radio circuit (*W1TP Telegraph & Scientific Instrument Museums*, 2005).

Fig. 28. T.R. McElroy Telegraph Apparatus Company circa 1948.

T.R. McElroy Company and its sister company Telegraph Apparatus Company (TAC) produced their own combination sets beginning in the 1940s (*ARRL* 1940; *QST*, July 1946; see Fig. 28). By 1962, Accentronome Corporation in Collingswood, New Jersey, produced the CODEME practice oscillator which could be used for tone and light practice and had a built-in key. It also featured a preset alphabet and preset Morse code combinations for practice (*CQ*, May 1962).

The McElroy, TAC and Codeme combination oscillators all included a built-in telegraph key. Most other manufacturers abandoned the built-in key designs and merely included a separate telegraph key mounted on a platform base together with the oscillator. This design continues to be popular today as shown by the ongoing demand for the William Nye oscillators which included a separate Speed X telegraph key.

After World War II, the U.S. Army and U.S. Air Force jointly developed their 1954 portable Code Training Set AN/GSC-T1A made by Taffet Radio Television Company. This set produced an audio tone or blinker flashes for up to ten students to practice transmission and reception. Ten practice keys were directly wired to the main control unit. This multi-user audio oscillator unit was intended for classroom, small groups and field training. (*War Dept. TM 11-437A*, 1954).

Homemade Oscillators. By the late 1930s, instructions for homemade oscillators were provided in many hobbyist and amateur project magazines and books. Toy promoters recommended constructing oscillators to learn basic wiring and to make wireless practice a feature of their toy sets. In 1945, *Radio For The Millions* offered a typical design for amateur hobbyists, incorporating a separate telegraph key, one tube power supply, simple audio circuit and used either headphones or a speaker assembly. Homemade practice oscillators continued to be recommended into the 1950s for use with phonograph and other training programs. For example, the 1951 Electronic Technical Institute (ETI) *Photosound Course* provided instructions for building a practice oscillator and connecting speakers through a radio circuit.

A Note On Keyers. By the late 1960s, practice designs combined sideswipe keys and variable oscillators into small portable devices known as keyers. These devices generally fall outside the scope of introductory Morse code training and use paddles instead of a traditional telegraph key. They also use electronic semi-conductor technology to modify the sender's transmission allowing perfectly timed signals and spacing, self-completing dots, dot-memory and semi-automatic transmission. Some keyers employ iambic keying (squeezing motions between the fingers) to produce alternating dots and dashes (Pierpont, 2002). Practice transmission speeds can be greatly enhanced with these devices up to 50 words per minute (Palomar, 1969). Although early keyers had been in existence since the late 1930s using tube driven circuitry, the emergence of solid state technology allowed the circuits to dramatically shrink in size. By combining this new solid state circuitry with an internal speaker, keyers formed a new generation of practice devices that brought the novice to even greater proficiency levels. Thus, keyers are generally used for advanced practice by those already familiar with the code.

PHONOGRAPH AND TAPE RECORDINGS

Of all the Morse code training methods, the use of phonograph and tape recordings offered the most easily accessible and least expensive approach for both professional and amateur operators. The growth of the phonograph industry in the early 1900s enabled entrepreneurs to develop training programs that did not require specialized devices like the Omnigraph. Mass production of inexpensive recordings featuring actual Morse code enabled students to learn at home using their home phonograph. The low cost of selling and shipping phonograph records made the development of mail order code training courses possible and increased the selection of

training programs available to the public.

Pre World War Two. A joint venture between the Marconi Wireless Telegraph Company and Victor Phonograph Company produced the first set of American Morse code training records in 1917 (Chadwick, 1918; Pierpont, 2002). This set consisted of 12 lessons recorded on six 78 RPM records. Lessons included letters and signs, sentences, press messages, messages with static interference, messages with errors and mixed character groups. Harry Chadwick, the Marconi Institute's Code and Traffic Instructor, authored an instruction manual issued by the Institute in 1918 and prepared the records himself (Chadwick, 1918). Though primarily intended for commercial wireless training, amateur radio operators and professional land line telegraphers also used the records.

The student began by listening to the records while reading code from the manual. After memorizing the code, sending practice followed, using a key and buzzer assembly sold separately by the Marconi Institute. Thereafter, the student played the record while simultaneously operating the key and buzzer. Lessons included individual characters, conventional signs and phrases, words and sentences, punctuation, practice with static, practice with signal interference, and speed and volume variations, press messages and standard signals used in maritime communications. The records were transcribed at 15 words per minute. (Chadwick, 1918).

A competing phonograph course emerged in 1922. The American Code Company of New York City advertised its phonograph course recorded by the celebrity wireless operator Jack Binns. An instructional textbook accompanied the course and claimed it could teach the Code in one evening.[5]

World War Two Era. New approaches to phonograph recordings were developed in World War II. Both the U.S. Army Signal Corps' and the U.S. Navy employed the unusual 1942 Gray Audograph Code Trainer by The Gray Manufacturing Company. This device introduced paper thin plastic records. Advertisements feature this instrument in photographs but nothing more is known of this early record training device. (*Telephony*, 1942; see Fig. 29)

Code teaching concepts underwent dramatic development during the War as the U.S.

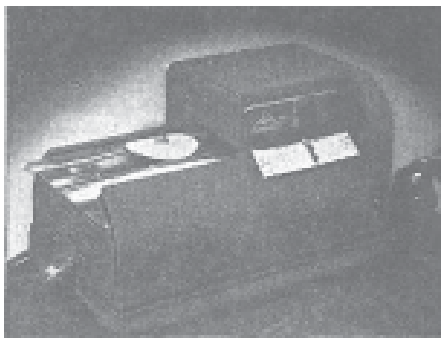


Fig. 29. U.S. Signal Corps' Gray Audograph Code Trainer, 1942.

government sponsored research to find ways of quickly training large numbers of radio operators. In 1942, the Linguaphone Institute in New York offered *A Course of Practical Instruction* containing 78 RPM records and an instruction booklet with ten lessons. The course targeted 15 words per minute proficiency by providing phonetic instruction where the student learned to recognize each character as a complete sound rather than individual dots and dashes. It also taught the student to "copy behind" the incoming code rather than "copying ahead." Copying behind meant simply that the student wrote the message after hearing complete words. But despite its modern approach, Linguaphone still instructed its students to make flash cards for memorization (Tuthill and Battey, 1942).

Dr. Fred S. Keller's studies for the U.S. Army in World War II resulted in the development of the "Code-Voice Method". Based on new concepts of audio-perception training, this method also taught the student to hear the unified sound pattern of the letter or character, as opposed to counting the individual dots and dashes, but carefully avoided rote memorization techniques. Keller's methods were adopted by the Army and the basic structure of his program was transferred onto paper tapes and records for large scale application (*War Dept. TM 11-459*, 1943). "Mastery" requirements for high speed and low speed operators began at 12 words per minute and progressed up to 25 words per minute for 75 words without error. (*War Dept. TM 11-443*, 1943). Keller's method emphasized the benefits of motivating the student through directing their own achievement of competency.

In 1943, The American Foundation for the Blind applied Keller's concepts with the *Talking Book: The Radio Code By The Voice-Code Method*. The 1959 *Rider Sound-N-Sight Code Course* also used the Code-Voice Method in its "Reinforced Learning System." The Rider course claimed students could reach 5 words per minute in approximately 13 hours of instruction; 13 words per minute in 20 hours; and 20 words per minute in 40 hours. It recommended two hours per day as the amount of daily practice that was most effective. (*Rider Sound-N-Sight*, 1959) That same year, the *Raybrun Code-Voice Method* 78 RPM two record set came available. Raybrun Company offered a similar course for the Boy Scouts that year entitled the *International Morse Code.*

1950s Expansion of Phonograph Recordings. The 1950s witnessed the tremendous growth of Morse code phonograph recordings that applied a wide variety of teaching approaches. At least fifteen different courses were offered by the U.S. government, radio supply manufacturers, and private entrepreneurs. Formats expanded to include the new 33

1/3 RPM Long Play (LP) record as well as 45 RPM short play records. The U.S. Navy continued producing its 78 RPM records, the *Morse Code Training Course* (Bureau of Naval Personnel, NAVPERS 11030).

The Insuline Corporation produced its *International Morse Code Course* based on the Navy's program using the Navy's "Phonetic Method of Instruction" (Tuthill and Battey, undated 1950s). Here the student memorized the dit-dah sound patterns making up each character by using the records in conjunction with homemade flash cards. Maximum practice speeds of 20 words per minute could be achieved by running the phonograph at higher revolutions per minute (Tuthill and Battey, undated 1950s).

The Electronic Technical Institute (ETI) offered its *Photosound Course* beginning in 1950 simultaneously teaching penmanship and typewriting skills along with code instruction. ETI's mail-order testing program spanned 72 recorded lessons to bring skill levels up to 20 words per minute including training with static and interference. The course expanded in 1955 to 150 lessons. (*Photosound*, 1950 and 1955) The U.S. Navy later offered the *Photosound Course* under the auspices of its *Radio Code Instructional Recordings* (*Radio Code*, undated 1950s).

Many commercial recordings in the 1950s and 1960s duplicated these methods. Allied Radio Corporation's 1957 *International Morse Code Course* followed almost the same lesson order as Insuline Corporation's course. Herman H. Smith's *International Morse Code Course* simply copied the Allied Radio Corporation's instruction manual including its schematics and diagrams (Smith, 1959). The Tandy Corporation produced Radio Shack's *Learning The International Morse Code* records in 1969 following a similar format to the Allied Radio and Herman Smith courses.

45 RPM Formats. Despite the popularity of 45 RPM records for single play music sales to the general public in the 1950s and 1960s, the 45 RPM format contained few offerings for Morse code instruction. In 1950, Brumberger included a 45 RPM *Morse Code Instruction Course* with its Codemaster Telegraph Signal Set. In 1956, *Uncle Sam's Morse Code Records* provided seven 45 RPM records incorporated the Dit-Dah Method used by the U.S. Air Force. This approach employed a pneumonic alphabet to memorize the individual code characters as auditory phrases or sound patterns. Practice examinations were given at 5,8,10,12,15, and 20 words per minute. (*Uncle Sam's*, 1956) American Electronics Company of New York (AMECO), also offered its Junior, Advanced and Senior Code Courses in 45 RPM formats.

Other Approaches and Formats. One of the most well known phonograph record sys-

tems was produced by Russell Farnsworth and released in LP format in 1959 by Epsilon Records. His records combined the application of teaching technologies by relying on original paper tapes to produce the master phonograph recordings of Morse code. The course included three LPs that ran at a code speed of 13 words per minute. Operation of the phonograph at 45 RPM increased the code speed to 17.5 words per minute. (*Revolutionary New Word Method*, 1959) Farnsworth's method reduced the audible spacing between the letters more quickly than the spacing between the words, much like the Audible Alphabet paper tape system did in 1902 (Smith, 1997). Still in use today on computer training programs, Farnsworth's method continues to be one of the most popular code teaching approaches (Smith, 1997).

By the 1960s, the recording industry had converted to the LP format. AMECO offered its new LP training records as part of a complete home study program, *Learn The Code With AMECO.* As late as 1962, advertisements indicated that AMECO's original four code courses were still available on 45 or 78 RPM formats (*QST*, January, 1962). However, most AMECO records through the rest of the decade came in LP format and the advanced supplemental practice records were only available on LPs. AMECO provided the broadest offering of any Morse code training records. All records were supplied with course instruction books and sample FCC license examinations. Lessons progressively moved the student up from 5 words per minute to 24 words per minute proficiency.

In 1963, Howard W. Sams and Company released its *International Code Training System* providing a complete programmed course for learning International Code. Materials included three 45 RPM records, three LP records and a comprehensive instruction guide developed by International Teaching Systems, Inc. Their so-called Programmed Method offered a unique approach to teaching Morse code based on increasing the complexity of each character to move from simple to more difficult letters, while instilling a sense that the code was an oral language to be learned in sound groups. (Howard W. Sam's, 1963)

Conversa-phone Institute's 1965 *International Morse Code* formalized a unique approach to code instruction. Conversa-phone provided instructions for changing the phonograph's turntable speed in order to obtain different code transmission rates for practice with their course materials. The recorded transmission speed could be increased proportionately when moving from 331/3 to 45 to 78 RPM speeds. For example, practice at 5 words per minute played at 33 1/3 RPM would become 7 words per minute at 45 RPM and 12 words per minute at 78

RPM. In this manner, Conversa-phone's single record with 11 practice bands could be utilized as though the record presented 33 different practice sessions. (*International Morse Code*, 1965) The 1959 *Rider Sound-N-Sight Code Course* and the Farnsworth recordings had previously experimented with a similar concept but only for selected bands on their records (*Rider Sound-N-Sight*, 1959; *Revolutionary New Word Method*, 1959).

Magnetic Tape Recordings. Magnetic tape recordings used for teaching Morse code first emerged in the 1940s. The McElroy Company offered free copies of their *Morse Code Course* as early as 1945 (*QST*, November, 1945). Ted McElroy made the hour long tape recording with the characters sent at 20 words per minute using ever decreasing spacing between each character. It is unclear whether the course was associated with any particular McElroy training device or whether instructions accompanied the tape (Pierpont, 2002).

In 1962, TapedCode offered magnetic tapes based on "Western Union, Railroad, Navy and Amateur experience". Their novice tape provided one hour of practice and an advanced tape provided two hours of practice at speeds up to 18 words per minute in five-character coded groups. The recordings were made on 1,200 foot lengths of Acetate tape stored on seven inch reels recorded in dual track at 3 ¾ inches per second. (*QST*, January, 1962)

Sound History Recording's 1964 course for the complete study of the *International Morse Code* claimed to teach copy speeds of 35 words per minute. Their two hour practice tapes were also available on seven inch reels accompanied by an instruction manual. (*QST*, April, 1964).

Cassettes and Computers. With the emergence of the compact cassette tape technology in the 1970s, many of the earlier phonograph and magnetic tape recordings of Morse code training programs were simply transcribed onto the new format. Together, phonograph LP records and cassette tape recordings targeted amateur radio hobbyists and maintained their popularity throughout the 1980s. Instructional recordings heavily marketed related products to amateurs, combining their LP or cassette recordings with other devices such as flashcards or inexpensive buzzer sets. A number of products were advertised as children's toys.

By the mid-1990s, cassette tape manufacturers continued to offer training courses no longer produced in phonograph record formats. But with the emergence of the home computer, the cassette tape recordings themselves began to be replaced by the newer floppy disk, and eventually the CDROM formats.

The growth of the internet by the late 1990s

opened an entirely new arena for free and even commercial software exchange of Morse code training programs. Today, many of the most popular courses can still be found in both cassette tape and CDROM formats, such as the broad product offerings of AMECO. Regardless of the format, however, the basic courses of instruction have remained the same. For example, the Amateur Radio Relay League still produces *Your Introduction to Morse Code* for both cassette tape and CDROM; providing the same 2.5 hours of practice lessons at speeds of 5 to 18 words per minute for both formats.

CONCLUSION

Together, Learner Sets, KOBs, disk and drum devices, paper tape machines and audio-visual trainers offered a range of effective mechanical means to teach and practice Morse code. Their simple designs and easy application permitted thousands of operators to learn the code for almost 150 years. The growth of the phonograph industry in the first third of the 20th Century and the use of ever more sophisticated electronics after World War II enabled manufacturers and entrepreneurs to develop new devices for teaching code. By the turn of the 20th Century, oscillators, electronic keyers and programs for the home computer dominated the market. While these 21st Century modern electronic tools offer greater variation in code speeds and timing practice than their mechanical predecessors, they foster standards in expected code proficiency similar to those first developed by telegraph and radio operators during the preceding 150 years.

Notes

1. By the time of their historic 1844 telegraph demonstrations, Samuel Morse and Alfred Vail had developed and then refined their code of dots and dashes commonly referred to as "Morse" code (Pope, 1888; Munro, 1891; Calvert, 2004). Certain changes were later adopted at international conferences in 1851 and 1854. The revised code came to be known as the "Continental" or "International" code and the original Morse code with slight modifications was known as the "American" or "American Morse" code (Coe, 1993; Calvert, 2004). Throughout this text, the term "Morse" code will be used broadly and will not distinguish between the applications of International, American or other derivative codes.
2. After the turn of the 20th Century, combination sets became more widely known as key-on-board, or KOB sets, to broadly describe all instruments consisting of a telegraph key mounted to the same base as some other item, such as a sounder. The term KOB was infrequently used before the 20th Century (Casale, 2006).
3. See Moreau, 1995; Perera, 1999; W1TP Telegraph & Scientific Instrument Museums, 2005; Casale, 2006.
4. See J.H. Bunnell, 1900; "The Electric Telegraph", 1909; MESCO No. 18; Telegraphy Successfully Learned At Home, 1912.
5. Jack Binns was the Marconi Wireless Operator aboard the liner Republic when it collided with the Italian cargo ship Florida on January 22, 1909. Binns made repairs and stayed at his station for the next 36 hours. He succeeded in guiding the rescue ship Baltic, through dense fog to save more than 1,500 passengers and crew. Binns became an instant

celebrity and later recorded a Morse code training course for the American Code Company. (Hancock, 1950; Loeterman, 1999; Pierpont, 2002)

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Photo Credits

All photographs are from the author's collection unless otherwise noted. The following have been graciously contributed courtesy of: Jim Kreuzer, Figs. 26 & 27; and Tom Perera, *W1TP Telegraph & Scientific Instrument Museums,* Fig. 24. The following figures were reproduced from Lynn Burlingame's *N7CFO Keyletter*, Fig. 15 and Fig. 25. Finally, Fig. 3 was reproduced from Louise Moreau's *Story of the Key*.

References

(1) Product Advertisements Contained In The Following:

ARRL Radio Amateurs Handbook, American Radio Relay League: 1940, 1942, 1956, 1962.

Commercial Telegraphers Journal: July, 1906.

CQ Magazine: May, 1962; May, 1963; December, 1964.

The Electrician: January, 1883.

Journal of the Telegraph: July 15, 1873; August 1, 1873.

Popular Mechanics: May, 1920.

QST: April, 1927; March, 1930; April, 1930; March, 1935; July, 1936; September, 1937; November, 1936; November, 1940; April, 1942; November, 1945; July, 1946; June, 1960; August, 1960; January, 1962; May, 1963; April, 1964; April, 1970; October, 1970.

Radio News: March, 1921; December, 1932.

Railroad Telegrapher: September, 1927; December, 1927.

(2) Online Internet Resources:

Code practice oscillator museum. Internet Site. Dave Meier. See http://www.n4mw.com.

Sparks telegraph key review. Internet Site. Russ Kleinman. See http://www.zianet.com/sparks/.

The telegraph office., Internet Site. Neal McEwen. See http://fohnix.metronet.com/~nmcewen/ref.html.

W1TP telegraph & scientific instrument museums. Internet Site. Tom Perera. See http://www.chss.montclair.edu/~pererat/telegraph.html.

(3) Jacket Notes and Instruction Manuals From Audio Recordings:

Chadwick, H. (1918). *Handbook of instructions and guide to Marconi wireless telegraph records for the Marconi Institute of New York*. New Jersey: Victor Talking Machine Co.

How to send and receive international Morse code. (1951). Raybrun code voice method. Orangeburg, New York: Raybrun Company.

Howard W. Sam's international code training system. (1963). International teaching systems, photofact publication no. 20138. Indianapolis,

Indiana: Howard W. Sam's and Co. Inc., The Bobbs-Merrill Company, Inc.

International Morse code course. (1957). Chicago: Allied Radio Corporation.

International Morse code. (1965). Farmingville , NY: Conversaphone Institute, Inc.

Learn the International Morse code. (1951). Raybrun code voice method. Orangeburg, New York: Raybrun Company.

Learning the international Morse code: Archer international Morse code beginner's course. (1969). Fort Worth, Texas: Prepared for Radio Shack by Bob Gunderson. Bates Music Publishing Corp.

Mastering the Morse code. (1957). Martin Schwartz. Mineola, Long Island, New York: American Electronics Co. "AMECO".

Morse code instruction course. (1950). Brooklyn, New York: Brumberger Corporation.

Photosound course. (1950). Phonograph recording jacket notes. Los Angeles: Electronic Technical Institute.

Photosound training. (1955). Phonograph recording nacket notes. Los Angeles: Electronic Technical Institute.

Radio code instructional recordings. (Undated 1950s). Bureau of Naval Personnel Training Aids No. 11035, U.S. Navy. Los Angeles: Electronic Technical Institute.

Revolutionary new word method to learn radio code. (1959). Donald Russell Farnsworth. Redwood City, California: Epsilon Records.

The Rider Sound-N-Sight code course instruction book. (1959). New York: John F. Rider.

Smith, Herman H. (1959). *Beginner's International Morse code course: the modern practical method*. Brooklyn, New York: Herman H. Smith, Inc.

Tuthill, Lt. Cdr. F.R.L. and Battey, Lt.(J.G.) E.L., (1942). *International Morse code: a course of practical instruction.* New York: Linguaphone Institute.

Tuthill, Lt. Commander F.R.L. and Battey, Lt. (J.G.) E. (undated 1950s). *International Morse code course.* Long Island City, New York: Insuline Corporation of America.

Uncle Sam's Morse code records. (1956). Chicago: ReCupidio Enterprises.

Your introduction to Morse code. (1997). West Hartford Connecticut: Amateur Radio Relay League.

(4) Other Resources:

Apparatus for self instruction in the continental telegraph code (1918, September). *The Wireless Age*. New York: The Wireless Press, Inc.

Calvert, J.B. (2004, May). The electro magnetic telegraph. *Telegraph: The history of telecommunications and related matters*. Denver: University of Denver see www.du.edu/~jcalvert/tel/telhom.htm.

Casale, J. (2006, May 14). Email Correspondence Re: Draft Book Review.

Coe, L. (1993). *The telegraph: a history of Morse's invention and its predecessors in the United States.* Jefferson, North Carolina: McFarland & Company.

*Central Electric Company catalo*g (1915). Chicago: Central Electric Company.

Department of the Army technical manual no. TM 11-437A and *Department of the Air Force technical order TO28-30GSCT1-6* jointly issued manual for code training set AN/GSC-T1A (1954, Novem-

ber 1). Washington, D.C.: US Army.

DeSoto, C. (1936). *Two hundred meters and down: the story of amateur radio*. West Hartford, Connecticut: The American Radio Relay League, Inc.

Edison, T. (1902). *Telegraphy self taught*. Chicago: Frederick Drake and Co.

The electric telegraph (1909). *Cyclopedia of applied electricity*. Chicago: American School of Correspondence.

Wireless and electrical cyclopedia no. 20 (1912). New York: The Electro-Importing Company.

Friedman, N. (1984, February). A clockwork omnigraph. *CQ Magazine.*

Gernsback, S., Secor, H.W. and Lescarboura, A. (1918). *Wireless course in twenty lessons*. New York: The Electro-Importing Company.

Hancock, H.E. (1950), *Wireless at sea: the first fifty years*. Chelmsford, England: Marconi International Marine Communications Company, Ltd.

The Instruct-O-Graph (Advertising literature) (1947). Chicago: Instruct-O-Graph Co.

J.H. Bunnell & Company catalogue and manual of telegraphy (1895). New York: J.H. Bunnell & Company.

J.H. Bunnell & Company catalogue and manual of telegraphy (1900). New York: J.H. Bunnell & Company.

Kirkpatrick, O.B. (1947). *Telegraphy: Continental and American Morse instruction for wireless and wire*. Chicago: Instruct-O-Graph Company.

Loeterman, Ben (Producer) (1999). "Rescue at sea", *The American Experience* (Television Series). Boston: WGBH Educational Foundation.

MESCO catalogue no. 18 (Undated). New York: Manhattan Electrical Supply Company.

MESCO catalogue no. 28 (1912). Something electrical for everybody. New York: Manhattan Electrical Supply Company.

MESCO manual of wireless telegraphy and catalogue of radio telegraph apparatus (Undated). New York: Manhattan Electrical Supply Company, Inc.

Moreau, L.R. (1995). *The story of the key*. Hertfordshire, England: Morsum Magnificat.

Munro, J. (1891). *Heroes of the telegraph*. London: The Religious Tract Society.

N7CFO keyletter: a newsletter for telegraph key collectors (June 8, 1992 to May 22, 2005), Bellevue, Washington: Lynn Burlingame.

Omnigraph Manufacturing Co. (Advertising literature) (1918). New York: Omnigraph Manufacturing Co.

Palomar engineers IC keyer (Technical data sheet) (1969). Escondido, California: Palomar Engineers.

Pennes, Dr. D. R. (2002, April and June).The omnigraph instruments. *Morsum Magnificat.*

Pennes, D. (2006, January). The omnigraph instruments. Key and telegraph column. *AWA Journal.* Vol. 47 No. 1.

Perera, T. (1999). *Telegraph collector's guide.* Maynard, Massachusetts: Artifax Books.

Pierpont, W. (2002, April 20). *The art & skill of radio-telegraphy*. Retrieved June 2005 from http://www.qsl.net/n9bor/n0hff.htm.

Pope, F. (1888, April). American inventors of the telegraph. *Century Magazine.* Vol. XXXV.

Practical radio: be a radio expert (1927). Washington, D.C.: National Radio Institute.

Prescott, G. (1866). *The history, theory and practice of the electric telegraph*. Boston: Ticknor and Fields.

Radio for the millions (1945). Popular Science Editorial Staff. New York: Popular Science Publishing Company.

Reid, J. D. (1879). *The telegraph in America*. New York: Derby Brothers.

Rich rewards in radio: be a radio expert (1934). Washington, D.C.: National Radio Institute.

Sears catalogue (1902). Chicago: Sears Roebuck and Company.

Smith,T. (1997, February-June-August-October). Morse learning methods. *Morsum Magnificat*.

St. John, T. (1910). *Things a boy should know about wireless*. New York: Thomas M. St. John.

Telegraphy successfully learned at home (1912, December). Valparaiso, Indiana: Dodge's Telegraph and Railway Institute.

Telephony: Special U.S. Army Signal Corps Issue (1942, November 28). *Telephony*.

War Department technical manual no. TM 11-432 code practice equipment (1942, February 2). Washington, D.C.: U.S. Government Printing Office.

War Department technical manual no. TM 11-443 for keyer TG-34-A (1943, October 25). Washington, D.C.: U.S. Government Printing Office.

War Department technical manual no. TM 11-447 for keyer TG-10-J (1943, May 15). Washington, D.C.: U.S. Government Printing Office.

War Department technical manual no. TM 11-45. Instructions for learning International Morse characters (1943, June 2). Washington, D.C.: U.S. Government Printing Office.

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David and Julia Bart are both from the Chicago area where they continue to reside with their two sons, John and Michael. They first met at the University of Chicago where they took a year long course in the history of science and natural philosophy.

David received both his Bachelor of Arts Degree in Anthropology and Statistics in 1985 and his Masters Degree in Business Administration in Finance and Accounting in 1993 at the University of Chicago. His career as a financial consultant and expert witness in corporate bankruptcy and commercial litigation has offered David many perspectives on the successes and failures of business enterprises. He has maintained a strong interest in the history of science and early communications since childhood, and has collected radio, telephone, phonograph and telegraph devices for over 20 years. David's interests now focus on the history of telegraphy and the application of this technology. His current research on the history of teaching the Morse code in America is being compiled into the first comprehensive book on the subject. David holds a Ham Radio License and is a long time member of the Antique Wireless Association. He is the President of the Antique Radio Club of Illinois and is an active member of the Michigan Antique Radio Club and the Indiana Historic Radio Society. He is the Chairman of the Museum Advisory Council for the Museum of Broadcast Communications in Chicago and has been recently named as Curator of its radio and television collections. David is currently consulting with the Newberry Library of Chicago on future exhibits exploring the impact of science and technology on society and the humanities.

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Together, David and Julia have enjoyed building their collection of communication devices and provided numerous demonstrations and programs for the Boy Scouts of America, school groups and local historical societies.

Julia and David Bart.